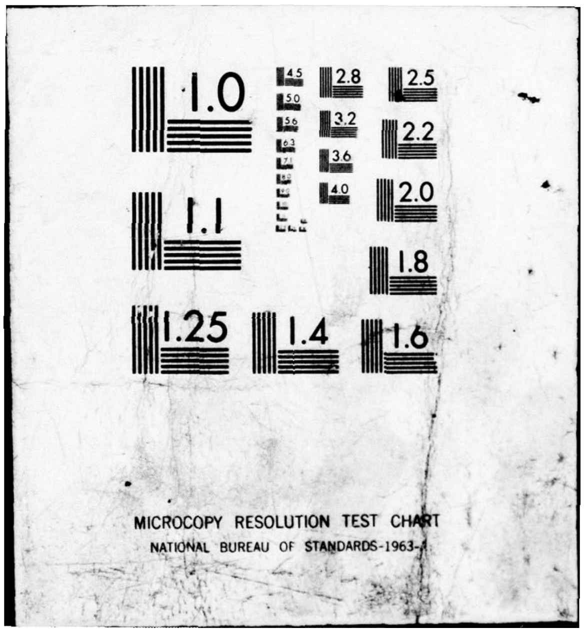
AD-A049 212 ARMY RESEARCH AND TECHNOLOGY LABS MOFFETT FIELD CA F/G 1/3
ARMY RESEARCH AND TECHNOLOGY LABORATORIES ANNUAL REPORT FY 77.(U)
1977

UNCLASSIFIED NL

| OF |

AD
A049 212

END
DATE
FILMED
2-78
DDC


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A


RTL
11
1997
12

...ents.

...was not entirely satisfactory as ...mounts of research dollars into ...ed to fulfill any existing Army ...this, the Army was authorized to ...quirements." This initiated the ...the first instance of the Army: ..., TRECOM, AVLABS, getting ...aterial development functions of ...ncluding Aviation, were merged ...erial Development and Readiness ...nsferred into AVSCOM when ...Aviation Systems Command at ...was also initiated by the Director ...ment the Army's aviation capa- ...ment functions of AVSCOM were ...ed, the Aviation Research and ...COM), in 1977.

TABLE OF CONTENTS

(1)

LIST OF FIGURES

LIST OF TABLES

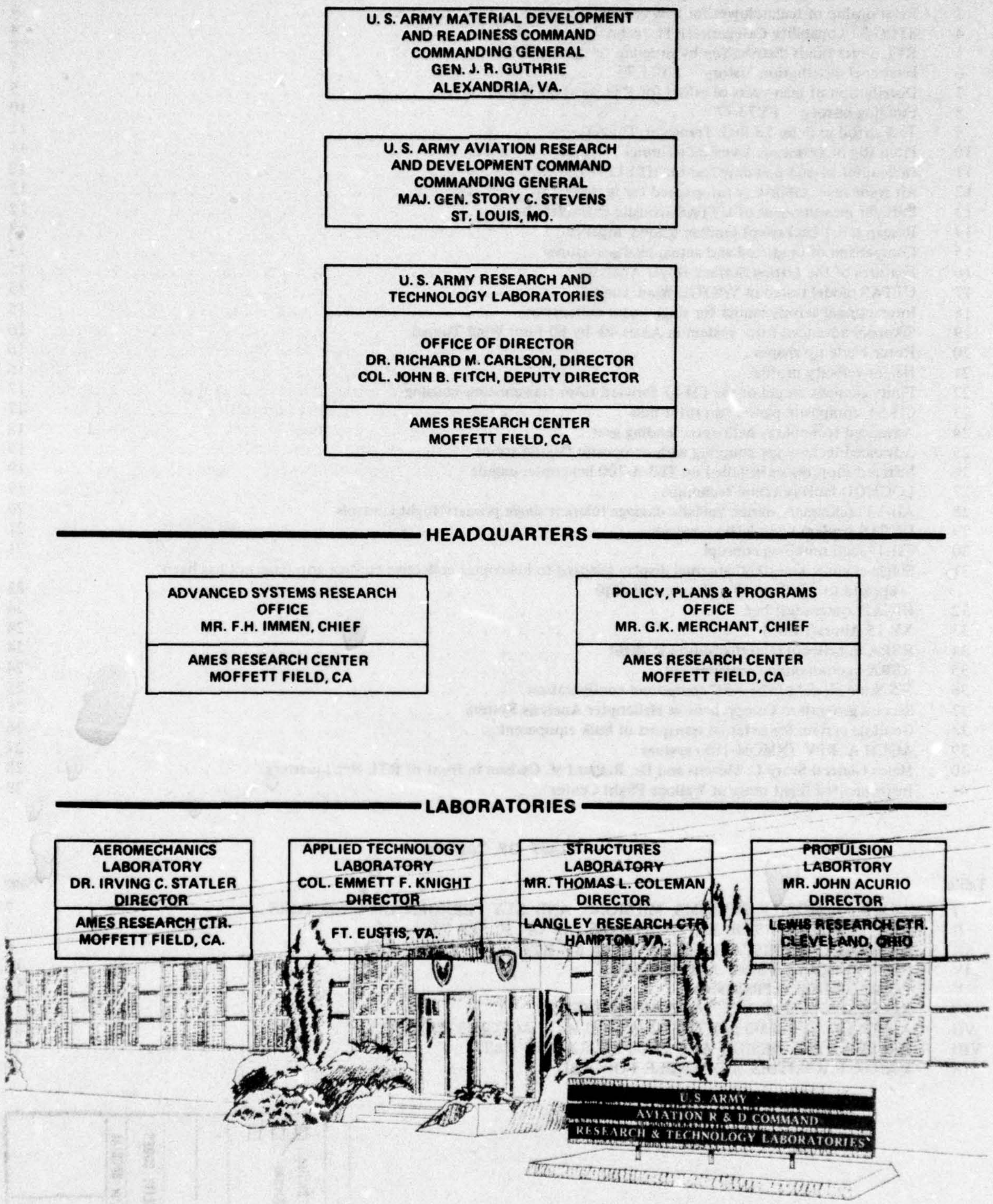


Figure 1. U.S. Army Airmobility R&D Laboratory organizational chart.

U.S ARMY RESEARCH AND TECHNOLOGY LABORATORIES
–FY77 REPORT OF ACTIVITIES–

INTRODUCTION

The U.S. Army Research and Technology Laboratories (RTL) perform the air mobility R&D efforts of the U.S. Army Aviation Research and Development Command (AVRADCOM). The capabilities of their staff of research, engineering, and support personnel span the sciences, disciplines, and technologies of Army aviation. The organization of RTL is represented by the chart (figure 1) located on the opposite page.

The Laboratories are charged with the following mission elements:

- Plan, develop, manage, and execute for the AVRADCOM the research and exploratory development programs and the advanced development program through demonstration of technology to provide a strong technical base for future development of superior airmobile systems.

- Manage and direct on a task basis, as assigned by Commander, AVRADCOM, tasks in advanced and engineering development subsequent to demonstration of technology.

- Maintain cognizance of, and provide consultative support for, advanced development subsequent to demonstration of technology, engineering development, operational development, and test for all Army airmobile systems.

- Provide technical consultation and independent risk assessment to Commander, AVRADCOM, for systems and components under development.

The Laboratories strive for improvement in both the development of a technology base and the support to system developers. By establishing and maintaining broad capabilities, the Laboratories have been able to achieve multidisciplinary capabilities to respond to urgent technical requirements of both the immediate and long-range needs of Army aviation, and have earned an international reputation for the outstanding achievements and abilities of their staff. The honors and awards received by staff members and the contributions they have made to the world's scientific literature during 1977 are listed in this report. Overviews are given for this year's accomplishments in the various technical areas to illustrate the scope and purposes of the Laboratories' research and development programs.

During the FY77 period, the Laboratories have operated under a continuing climate of austerity in terms of manpower and funds. Realistic assessment of the Laboratories' goals relative to the available resources requires a continual adaptation of the Laboratories' program structure to assure that short- and long-range research, and development efforts are best directed to activities which will achieve the Army objectives for which AVRADCOM is responsible.

The FY77 Annual Laboratory Posture Report is prepared in response to the U.S. Army Material Development and Readiness Command instructions and guidance.

KEY EXECUTIVE ITEMS

NOTEWORTHY MANAGEMENT ITEMS

The name of the U.S. Army Air Mobility Research and Development Laboratory, NASA Ames Research Center, Moffett Field, California, was changed to U.S. Army Research and Technology Laboratories (AVRADCOM), effective August 30. AVRADCOM is the acronym for U.S. Army Aviation Research and Development Command, St. Louis, Mo., the Laboratories' higher command.

The Laboratories' four subordinate directorates, were also renamed as follows: The Ames Directorate is now the Aeromechanics Laboratory, Moffett Field, Ca.; the Lewis Directorate is now the Propulsion Laboratory, NASA Lewis Research Center, Cleveland, Ohio; the Eustis Directorate is now the Applied Technology Laboratory, Fort Eustis, Virginia; and the Langley Directorate is now the Structures Laboratory, NASA Langley Research Center, Hampton, Virginia.

The preliminary design functions within RTL were consolidated as part of the reorganizations of AVRADCOM and RTL. Previously, the preliminary design function was performed at four different locations. Now, the Design Analysis Branch of the Directorate for Development and Engineering will be responsible for maintenance of performance data on current Army aviation systems and for assessing the effect of product improvements and engineering change proposals. The Preliminary Design Team in the Advanced Systems Research Office (ASRO) will be responsible for methods development, correlation between theory and test data, and conceptual design of emerging aircraft systems.

The most unique aspect of the management of RTL lies in its ability to operate as a single operating entity, although its four separate laboratories are geographically dispersed from coast to coast. The Laboratories operate under a single Director and are managed as a unit. This unity of management allows for full responsiveness to the needs of the various program managers, as well as allowing the entire capability of the Laboratories to be quickly brought to bear on any specific objective.

Simulation technology provides a good example of RTL's total integrated systems approach to research and development involving conceptual designs, preliminary and detail design tradeoffs, man-machine interactions, mission capabilities, and product improvement evaluation, as well as RTL's policy of close cooperation with other organizations in order to better accomplish its mission and eliminate duplication. RTL are in the process of developing a new ground-based flight simulator to realistically represent motion and visual cues for Army low level missions for rotary wing aircraft. The detailed specification will depend on trade-offs based on behavioral research and on visual system hardware development programs being carried out by RTL, NASA, PM-TRADE, the Air Force, Navy, other Government organizations, and commercial manufacturers. The Army/NASA Joint Agreement will be exploited to obtain maximum facility and technical support during this development phase. A close working arrangement will be established and maintained with the PM-TRADE for technical guidance related to advanced simulation technology development.

The In-House Laboratory Independent Research Program sponsored by DCSRDA was expanded during FY77. Based upon RTL's previous successes in this area, FY77 funds were expanded from $90,000 to $150,000. This increase enabled RTL to initiate a research project at the Applied Technology Laboratory to investigate the mechanical properties of elastomeric bearings, as well as to continue the highly successful rotor acoustic research being done by the Aeromechanics Laboratory.

RTL continued to provide total Laboratory support to AVRADCOM Program Managers. During 1977 RTL engineering provided over 10,000 man days of support to Source Selection Boards, technical risk assessments, and other program manager activities.

The Plans, Programs and Budget Division of HQ RTL continued to provide valuable management assistance in the administration of Laboratory programs, in the form of monthly Laboratory Management Indicators. The indicator objectives are three-fold, providing the Command Group with

- Statistical facts
- Graphic trends and comparisons
- Narrative analysis

This procedure, with minor modifications, was used in providing the quarterly Command Review and Analysis presentation to the CG AVRADCOM. The R&A format was tailored to meet the requirements of the Commander's Total Management System and covers the general areas of

- Key Drivers
- Workload Indicators
- Thrust Items

In another area of management, the vigorous liaison program between RTL and the user of Army aircraft has been maintained. Frequent contacts have been held with the TRADOC and FORSCOM. During FY77, 16 TRADOC liaison trips were accomplished, as well as two field engineer troop visitations were conducted.

The Laboratories were also visited during FY77 by a number of key individuals from the Office of the Secretary of Defense, the Department of the Army, HQ DARCOM, TRADOC, FORSCOM, the FAA, and others interested in air mobility R&D.

Technical decision and exchange of rotorcraft technology is sponsored by two primary organizations, the American Helicopter Society and the Advisory Group for Aerospace Research and Development. RTL personnel are in the forefront of activity at all levels in both of these organizations and in such organizations as the American Institute of Aeronautics and Astronautics and Society of Automotive Engineers as well. The activities and publications of these organizations provide the forum required for dissemination and review of the technology and the interaction required to advance the state-of-the-art. Another method for achieving technology exchange is exemplified by Memoranda of Understanding and The Technical Cooperation Program activities. In areas where selected efforts are being carried out by research organizations of other governments, cooperative efforts which provide for interface between researchers and avoid duplication of effort are undertaken if mutually beneficial. These efforts can result in development of technology at substantially reduced costs to each participant.

NOTEWORTHY TECHNICAL ITEMS

To the R&D scientist, all technical achievements are noteworthy. However, for this report, a few have been selected as particularly noteworthy and summarized here, with more detail provided in the technical achievements section. The most vital function of any military R&D organization is the application of these noteworthy tehnical achievements, or any other achievements for that matter, to both military and commercial hardware. This transfer of technology is a major ongoing RTL effort, and is discussed following the technical items.

The Army/NASA XV-15 Tilt-Rotor Aircraft Program has made significant progress during FY77. The program has advanced through final assembly into hover and air taxi tests, with the first flight occurring in May, 1977. Component and system testing have progressed to include ground tiedown testing, using one of the aircraft. Current plans are to test one of the aircraft in the Ames 40- by 80-Foot Wind Tunnel prior to further flight testing.

The Rotor System Research Aircraft (RSRA) is another joint Army/NASA program which will provide a first-time flight research capability for evaluation of new advanced rotor concepts, verification of supporting research technologies, and evaluation and comparison of product improvement rotors. One of the two aircraft has been tested as a pure helicopter, with first flight occurring in October, 1976. That aircraft is presently being reconfigured as a compound helicopter with wings and auxiliary thrust engines. The second aircraft is being assembled with an active transmission isolation system and will be flown first as a pure helicopter.

The Advancing Blade Concept (ABC) aircraft incorporates a coaxial, counter-rotating, hingeless rotor system, which offers several advantages over conventional rotor systems. The flight test program has successfully demonstrated the concept in the helicopter configuration. The ABC was originally an Army program and included testing as a compound configuration using auxiliary thrust engines. The compound version was eliminated because of funding limitations. However, testing in a compound configuration has been reinstated as a joint Army/Navy/NASA program. The objective of the flight tests with auxiliary propulsion is to demonstrate feasibility of the ABC concept to achieve high speed flight up to 300 knots. The aircraft is currently being reconfigured to the compound version, with the first flight as a compound scheduled for February, 1978.

Developmental flight testing is a "must" tool for any new airmobile concept. However, it is a costly effort, usually requiring iterative development steps and considerable flight testing. To reduce both cost and developmental time, a Second Generation Comprehensive Helicopter Analysis System is being developed to permit analysis of rotorcraft characteristics such as performance, stability and control, structural loads, aeroelastic stability, and acoustics. A joint Government/Industry Working Group has prepared a draft specification detailing the requirements for the analysis to meet both Government and Industry needs. Contracts have been let to three firms to conduct pre-design studies. The purpose of these studies is to improve the specification; define the system capability; and produce a conceptual design, a design specification, and a development plan.

Contracts were awarded in February, 1977, for the development of two 800 horsepower advanced technology demonstrator engine designs. The objective of the program is to demonstrate advanced turboshaft engines having significant improvements in performance, capability, and cost. This demonstration will be accomplished by development and testing of two designs incorporating advanced components and gas generator technology.

For RTL, the transfer of technology must be directed initially to Army operational airmobile systems or emerging systems such as the Black Hawk and the AAH helicopters. Equally important is the transfusion of the technology into other military services, governmental agencies, and commercial application. The transfusion of technology developed in the 6.1 and 6.2 areas is usually not nearly so obvious as it is in the 6.3 and later developments. On the other hand, very frequently 6.3 is not truly a technology transfer, but, rather, a supporting of a continuing development of a concept generated by a particular contractor. Developments from the 6.1 and 6.2 activities generally are provided to the industry and to the users through the mechanisms of reports and presentations at technical symposia, conferences and meetings. Another means is by way of face-to-face meetings with contractors' and users' representatives. These include not only the relatively frequent visits by industry, but actual "working visits" with both prime and subsystem contractors. In this category, also, is the Laboratories' participation in Source Selection Evaluation Boards (SSEBs); but perhaps even more important has been the participation in ad hoc studies on behalf of the Project Managers such as AAH and RPV. A few specific examples of technology transfer that have resulted from these exchanges are the following:

- Distribution and assistance in assuring proper understanding and operation of the "Flex Beam Air Resonance" rotor stability analysis program to all major U.S. helicopter industries.

- Transonic rotor blade numerical codes to the helicopter industry.

- In-flight acoustic measurement data to Hughes and Sikorsky. (Limited distribution because of Army classification of data).

- ARMS Model (Aircraft Reliability Maintainability Simulators) to TRADOC elements and aircraft developers (e.g., TRASANA, Hughes, Bell, and Lockheed).

The U.S. Army Research and Development Command and the U.S. Army Training and Doctrine Command cosponsored an Advanced Planning Briefing for Industry (APBI). The briefing was a part of a continuing effort to keep industry informed concerning the Army's long-range development objectives and goals in the field of aviation. The scope of the briefing encompassed the entire spectrum of anticipated requirements for Army aviation systems and subsystems. The U.S. Army Research and Technology Laboratories participated in this briefing by presenting the Army aviation technology base program with primary interest in aeromechanics, structures, propulsion and subsystems/R&M.

MANAGEMENT

PROGRAM STRUCTURE

The interest of the Army in utilizing the air space has added another dimension to the battlefield for the land combat functions of mobility, intelligence, firepower, combat service support, and command, control and communications. The current Army operational airmobile systems, developing systems, and R&D planning concepts are shown in figure 2.

LAND COMBAT FUNCTION	MISSION	OPERATIONAL SYSTEMS	DEVELOPING SYSTEMS				R&D PLANNING CONCEPTS							
			AAH	UTTAS	RPV	CH-47D*	ASH	HLH	OV-X	SUR/VTOL	AAWS	LAH	LUH	ITAV
MOBILITY	UTILITY	UH-1		■									▨	
	MEDIUM LIFT	CH-47				■								
	CARGO TRANSPORT	CH-54						▨						
INTELLIGENCE	RSTA/D	LOH					■			▨				
		OV-1D			■				▨					
FIREPOWER	TACTICAL MOBILITY	UH-1	■									▨		
	DESTROY	AH-1	■								▨			
COMBAT SERVICE SUPPORT	UTILITY	UH-1		■									▨	
	MEDIUM LIFT	CH-47				■								
	CARGO TRANSPORT	CH-54						▨						
COMMAND, CONTROL & COMMUNICATION	AVIATION SUPPORT	LOH											▨	▨
		UH-1		■									▨	

*MAJOR MODERNIZATION PROGRAM

Figure 2. Land combat function mission systems.

The Army's aviation needs, represented by the developing airmobile systems and R&D planning concepts, have been analyzed to define technology voids. The R&D program structure must reflect not only the response to the currently projected capability requirements, but also the need for a technological base that will fill these voids and will stimulate innovative and imaginative airmobile missions, functions, and concepts.

The R&D program of RTL provides the technological base required for fielding these systems with significant improvements over current aircraft in survivability, reliability, maintainability, durability, and operational performance and effectiveness.

To maintain and expand the technological base required in the development of advanced airmobile systems, RTL formulate a coordinated program of research, exploratory development, and advanced development in the basic sciences, basic and supporting technologies, and advanced subsystems and technology demonstration. A life-cycle representation of this program structure relating to RTL technologies and disciplines is shown in figure 3.

The RTL have prepared the sixth (FY78) edition of the Army Aviation Research, Development, Test, and Engineering (RDT&E) Plan. The Plan is the AVRADCOM response to the requirement for a Consolidated R&D Plan and addresses the near and long-term RDT&E activities that are required for achieving the Army objectives and material needs for which AVRADCOM is responsible. This plan presents a time-phased analysis and presentation of the scientific and technological programs that are required for the development of advanced airmobile systems. It is the purpose of this document to set forth plans and objectives for Army aviation research and development activities for the FY78-97 period, with particular emphasis on the period from the present to FY82. It presents, quantitatively, the relationship between the current technological base and future requirements, while taking into account the potential impact of advances in fundamental technologies.

The RTL R&D program for FY77 was consistent with the goals and objectives defined in the Army Aviation RDT&E Plan and was oriented, to the maximum extent possible, in the directions of DARCOM goals, applicable Catalog of Approved Requirements Document (SECRET) requirements, and Science and Technology Objective Guide, FY77 (STOG-77) (CONFIDENTIAL).

The STOG-77 was first published in May, 1976 with four basic goals:

- To bring Army user and developer communities together early in the planning stages of the material acquisition cycle in order to assess capability gaps and identify future priority needs.

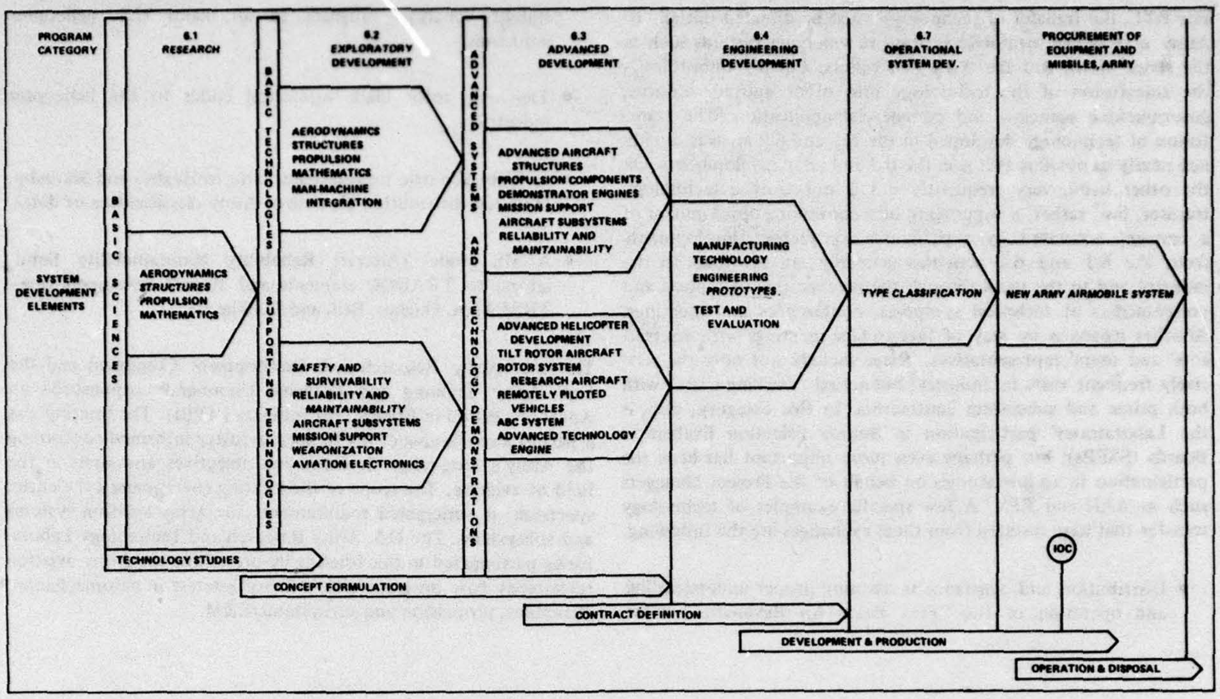


Figure 3. Relationship of technologies for new airmobile systems.

- To provide a single guidance document which lists priorities for specific Science and Technology (S&T) objectives for in-house R&D organizations and civilian industry.

- To provide a management tool by which S&T program relevance to priority Army needs may be established and evaluated.

- To obtain user assistance, especially in terms of feasibility, risk, time, cost/affordability, and compatibility with Army doctrine, in the trade-off assessments of alternative technical proposals from Army R&D organizations and civilian industry.

The STOG is intended to consolidate and ultimately replace two existing documents: Operational Capability Objectives and ODCSOPS technology base goals.

RTL applied nearly all of its 6.1, 6.2, and 6.3 R&D funds in research efforts applicable to one or more STOG-77 requirements pertaining to Army air mobility development. A matrix of the STOG-77 Capability Categories applicable to Army air mobility, as aligned with the RTL technology disciplines, is presented in figure 4.

While the RDT&E Plan establishes the basis for programming, it is not in itself a program. Programming is accomplished subsequent to the application of funds. The distribution of RTL FY77 direct funds by program category is shown in figure 5. This distribution applies only to RTL and should not be construed as the total distribution of R&D funds for Army aviation. Figure 5 does not include 6.4 activities which are primarily the responsibility of the Directorate for Development and Engineering of the PMs, AVRADCOM, nor any 6.7 category funds (Operational Systems), since there are not any RTL programs in this category.

The small amount ($639,000 or 1-1/2%) spent on management and support (6.5 program category) consists of expenditures for operation of RTL headquarters at Ames Research Center ($600,000) and operation of the DARCOM West Coast Technical Industrial Liaison Office ($39,000) at Pasadena, CA. However, Headquarters, RTL, located at Ames Research Center, is not charged for the use of facilities or support services provided by NASA. This is an example of improving the effectiveness of national resource utilization as stated in the Preface to this report.

RTL program structure aligned with a matrix of 6.1, 6.2, and 6.3 program categories and developmental functional areas is presented in Appendix A. The FY77 RTL R&D funds are also shown at the tech area/task level, with the amount and ratio (percent) of each program category funds devoted to a particular technology.

S&T OBJECTIVES		RTL APPLICABLE TECHNOLOGY DISCIPLINE										
NO.	NOMENCLATURE	Aerodynamics	Structures	Propulsion	R&M	S&S	Mission Support	Acft Subsystems	Man-Machine Integ.	Simulation	RPV	Acft Weaponization
77-7.1	Fire & Forget Weapons System											X
77-7.2	Helicopter Survivability	X	X	X		X	X	X	X			X
77-7.3	Adverse Weather Mission Capability	X				X	X	X	X			X
77-7.5	RSTA										X	
77-7.7	External Cargo Handling					X	X	X	X			
77-7.8	Ship-To-Shore Logistics	X	X	X	X	X	X	X	X	X		
77-7.11	Life Cycle Costs	X	X	X	X		X	X	X	X	X	X
77-7.12	Advanced Structural Materials		X		X	X						
77-7.13	Rotary-Wing Pilot Workload	X		X			X	X	X	X		X
77-7.16	Man-Machine Interface	X			X	X		X	X	X		X
77-7.17	Vehicle/Mission Simulators	X	X	X	X	X	X	X	X	X	X	X

Figure 4. STOG-77 Capability Categories/RTL technology disciplines.

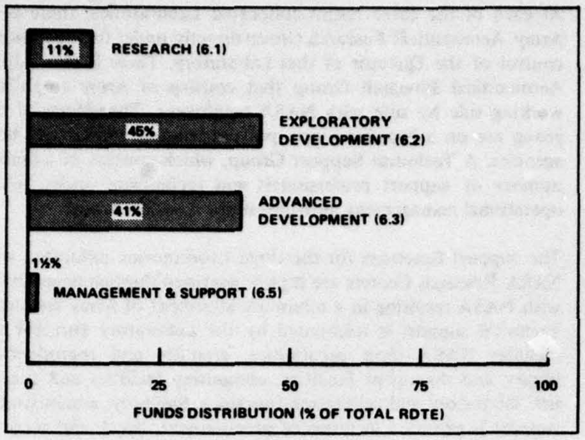


Figure 5. RTL direct funds distribution by program category (FY77).

PERSONNEL AND MANPOWER

The primary emphasis of the RTL manpower and personnel management programs during FY77 was one of retrenchment to comply with various restrictions and reductions imposed throughout the fiscal year. In FY77, RTL were required to reduce their authorized civilian spaces by 16; their authorized military spaces by one; and, in addition, to eliminate nine temporary part-time positions. These space reductions resulted in a decline in the on-board strength of the Laboratories to a level below the initial strength of AMRDL when it was formed (see figure 6). The projected space reductions in FY78 will further reduce the actual number of personnel on-board. The impact of these space reductions becomes more significant as a result of the ancillary constraints of average grade control; control of high grade positions; and the preclusion from effecting reductions in force procedures. The distribution of technical and administrative personnel is shown in figure 7 which also provides a profile of the skill level of the technical personnel.

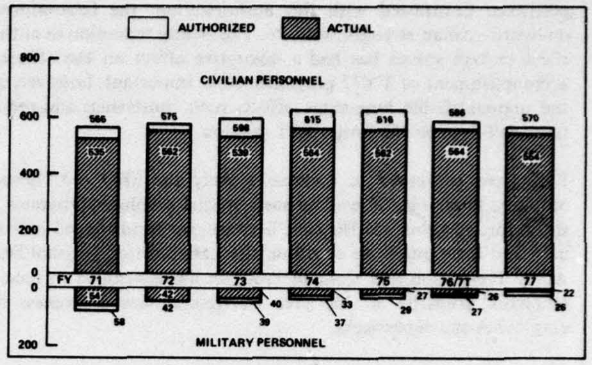


Figure 6. Personnel distribution history – FY71-77.

Military Manpower Resources – The Laboratories continue to experience a steady reduction in military space authorizations. Since their establishment, the Laboratories' military authorizations have decreased by 55%, from 58 to 26 spaces. The continuation of this trend has had a detrimental effect on the military/civilian engineering interface that is required both for the development of a strong technical base and for the development of Army airmobile systems. This military/civilian interface is essential to the identification and development of systems to meet the needs

A. DISTRIBUTION OF MANYEARS OF EFFORT AS OF 30 SEPT 77	ARMY RDTE HQ. DARCOM	ARMY RDTE OTHER DARCOM	ARMY RDTE NON-DARCOM	ARMY PROCUREMENT SUPPORTED DIRECTLY OR INDIRECTLY BY DARCOM	ARMY PROCUREMENT NON-DARCOM	ARMY OMA DARCOM	ARMY OMA NON-DARCOM	TOTAL ALL APPROP	ALL OTHER APPROP	TOTAL ALL SOURCES
CIVILIAN PERSONNEL TOTAL		554						554		554
*SEE B BELOW — TECHNICAL TOTAL (PROF & TECHNICIAN)		326						326		326
ADMINISTRATIVE TOTAL		228						228		228
SUPPORT & G & A TOTAL										
MILITARY PERSONNEL TOTAL		22						22		22
TECHNICAL TOTAL (PROF & TECHNICIAN)		18						18		18
ADMINISTRATIVE TOTAL		4						4		4
SUPPORT & G & A TOTAL		–						–		–

B. PROFILE OF TECHNICAL PERSONNEL SKILLS LEVEL	DOCTORS #	DOCTORS AVG AGE	DOCTORS AVG GRADE	DOCTORS AVG YRS GVT SVC	DOCTORS %**	MASTERS #	MASTERS AVG AGE	MASTERS AVG GRADE	MASTERS AVG YRS GVT SVC	MASTERS %**	BACHELORS #	BACHELORS AVG AGE	BACHELORS AVG GRADE	BACHELORS AVG YRS GVT SVC	BACHELORS %**	OTHER #	OTHER AVG AGE	OTHER AVG GRADE	OTHER AVG YRS GVT SVC	OTHER %**	TOTAL #
CIVILIAN	30	37	12.1	7	7	67	37	12.5	12	2	14.0	43	12.1	14	-7	89	43	9.5	19	2	326
MILITARY OFCRS(01-010)	1	35	3	1	-50	7	40	4.9	3	–	3	43	4.7	7	-40	2	42	5.0	1	100	13
MILITARY WO(W1-W4)	–	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–		–	–	–
MILITARY EM(E1-E9)	–	–	–	–		1	28	5	1	100	1	31	5	2	–	4	28	E5	4	–	6

C. WORKFORCE STRENGTH IN PEOPLE ON BOARD AS OF 30 SEP 77	
CIVILIAN	554
MILITARY	22
TOTAL	576

**PERCENT CHANGE (+/-) SINCE FY 76 IN NUMBER (#) ONLY.

Figure 7. Distribution of man-years of effort for RTL as of 30 Sep 77.

of the user community and is vital to the effectiveness of the Laboratories' liaison efforts with TRADOC and FORSCOM. The continued reductions also have had an adverse effect on the future of military managers, in that key developmental opportunities are being severely restricted.

Civilian Manpower Resources – The civilian employment ceilings for RTL at the end of FY77 was 570 full-time permanent positions. Contrasted with this authorization, the Laboratories' on-board civilian strength was 526. The steady reduction in authorized civilian spaces has had a disruptive effect on the efficient accomplishment of FY77 programs. More important, however, are the unquantifiable long-range effects such constraings and reductions will have on the future RTL mission.

RTL have continued to endorse actively the EEO and Upward Mobility Programs, as well as such special emphasis programs as those for individuals of Hispanic heritage, for handicapped individuals, and for women. In addition, the Laboratories' Alcohol Drug Abuse Prevention and Control Program has continued to receive emphasis primarily in the area of training and awareness for employees and supervisors.

ORGANIZATIONAL CONFIGURATION AND MANAGEMENT IMPROVEMENTS

The U.S. Army Aviation R&D Command Research and Technology Laboratories are an integrated organization with a Headquarters and four operating Laboratories, as shown in figure 1 (opposite page 1). RTL are the laboratory capability of the U.S. Army Aviation R&D Command and are the Army's principal aeronautical research and development field activity.

The concept of operations established for RTL emphasizes the following:

- Ensure that a balanced total RTL R&D program is established and achieved;
- Increase the effectiveness of support to product developers to ensure improvements in their airmobile systems;
- Provide means for assuring an orderly continuity of efforts from research through exploratory development to demonstration of technology and transfer of knowledge to developers and contractors for application.

A management team, composed of the senior managers of the Laboratories assists the Director in assuring that effective utilization is made of resources for successful mission accomplishment.

The RTL management team directs its activities to achieve balance between the development and demonstration of technology and the requirement for support of specific airmobile systems concepts. All four of the subordinate Laboratories are involved in all aspects of the RTL mission; however, specific emphasis is given to particular disciplines in each of the Laboratories. For example, in the three Laboratories collocated with NASA, the largest part of the effort is directed toward research and exploratory development to increase knowledge in the physical and behavioral sciences. Such efforts may, in some cases, be orientated toward recognized operational objectives, but may not relate directly to a specific system. Conversely, the primary mission of the Applied Technology Laboratory is in the areas of technological application, military operations technology, and technical support to systems developers. The Applied Technology Laboratory plays a major role in the transfer of technology to industry and the Army users.

At each of the three NASA-collocated Laboratories, there is an Army Aeronautical Research Group directly under the operational control of the Director of that Laboratory. There is also a Joint Aeronautical Research Group that consists of Army employees working side by side with NASA employees. The efforts of this group are on a broader scope, pursuing mutual interests of both agencies. A Technical Support Group, which consists of a limited number of support professionals and technicians under NASA operational management, provides support to the Army.

The support functions for the three Laboratories collocated with NASA Research Centers are largely provided through negotiations with NASA resulting in a minimum allotment of Army resources. Technical support is negotiated by the Laboratory Director and includes NASA shop capabilities, graphics and reproduction, library and document facilities, computing facilities and specialists' laboratory and calibration functions. Similarly, administrative support is provided in terms of procurement, fiscal and accounting, travel, and other associated services. Monetary resources, for contracting purposes, are supplied to NASA on a reimbursable authority. Program authority is exercised over Army resources by RTL through allocation of program resources in accordance with a stipulated plan. Effectiveness and conformance are judged by audit procedures. A limited in-house administrative capability is provided in each of these Laboratories to monitor the administrative support services, prepare programs, and perform necessary regulatory functions.

A comparable support function by Army personnel exists at the Applied Technology Laboratory. A Contracting Division, a Legal Division, a Technical Support Division, and an Administrative Support Division report directly to the Director, Applied Technology Laboratory. The Contracting and Legal Divisions are total RTL resources, and, at the discretion of the RTL Director, service the other three Laboratories as required. Such instances would occur, for example, when an Army awarded contract is dictated rather than a NASA contract.

The RTL Director controls, through the Headquarters Policy, Plans, and Programs Office, the use of all money resources against approved documents. The authority to contract, delegated to the Director, RTL, is redelegated to the Director, Applied Technology Laboratory, who exercises the authority in accordance with approved program through the contracting division located at the Applied Technology Laboratory. Funds supplied to NASA for contract are controlled by the Directors of the individual Laboratories according to a program approved by the Director, RTL.

Throughout the RTL, the concept of vertical alignment is applied to reduce administrative burden and to provide maximum flexibility in the use of technical manpower against continually varying technical emphases. Vertical alignment provides the ability to shift readily the staff of RTL without detailing, including the mix of specialties and grade levels, in response to the current need, rather than in conformance to an arbitrary organization. Vertical alignment contributes greatly to increased productivity, reduces requirements for services from supporting organizations, and has demonstrated its value in increased responsiveness to customer needs.

Integration of Army aviation R&D capability into RTL as a single operating unit has resulted in effective resource utilization and program responsiveness. It has provided a management structure with maximum flexibility in the utilization of manpower resources and has established a single point of contact for laboratory assistance to system and product developers. Further integration of Army aviation, scientific, and engineering capability is warranted and should be pursued. The Aeromechanics Laboratory is participating in a Memorandum of Understanding (MOU) arranged

between the Army (RTL) and the French Office National d'Etudes de Recherches Aerospatiales. Under this management agreement, specific areas of mutual research interest are spelled out; and there is an extensive interchange of research information. Research engineers from France work within the Laboratory, and RTL engineers work in France on rotating assignments. Extremely complex problems, such as dynamic stall of rotor blades, have benefited directly from such a close interchange. A similar MOU is under discussion with the Federal Republic of Germany.

PLANNING

The Army Aviation RDT&E Plan provides the basis for the Laboratories' program planning. The RDT&E Plan addresses the plans and objectives for Army Aviation R&D activities for the next 20-year period, with particular emphasis on the near-term 5-year period. It relates, in a qualitative manner, the current technological base to the projected future requirements.

The specific emphases for revision in the FY78 update of the plan (October 1977 publication date) were:

- Realign programs with updated DA Science and Technology Objectives Guide (STOG-78) (CONFIDENTIAL).
- Reappraise all near- and far-term objectives with respect to STOG-78, Catalog of Approval Requirements Document (CARDS), July 1973 (SECRET), and DARCOM MBO Goals.
- Update status of all Army airmobile systems discussed in the Plan.
- Update status of technology sections.
- Discontinue publication of classified supplement to the Plan.

The Plan seeks to explore all viable options for future systems with the goal of providing a range of choices and a means for selecting candidates for development when required. As the operational dates become more distant, a larger number of options can be pursued at a more fundamental level of research. The Plan is intended to be a management tool to provide recognition of acknowledged requirements and interdependence of necessary technological achievements. While the Plan establishes the basis for programming, it is not in itself a program. It is not constrained by available resources in its stated objectives and corresponding R&D to implement them.

The Plan focuses RDT&E activities to guide the Army's funds into areas of greatest effectiveness. Thus, R&D effort is directed toward ensuring that the most advanced technology is available for use in near-term projects. For new systems further downstream, the effort is directed toward minimizing technical barriers, optimizing key performance factors, and narrowing the options to the most viable. Plans for development of new systems, technological improvement objectives, plans to reach these objectives, and past trends are described in the document.

Desired capabilities and Initial Operational Capability (IOC) dates for most of the projected airmobile systems are based on currently available documentation. For each of the Army's airmobile systems, the mission, key factors, and salient characteristics that determine its performance requirements are discussed in detail in the Plan. These considerations are summarized in Table I. The missions and the key performance factors are based on current projections of the Army's aviation needs. The threat is continuously analyzed and maintained. Conceptual and design studies are conducted to assess advances in each area of technology with

TABLE I. ARMY AIRMOBILE SYSTEMS, MISSIONS, AND KEY PERFORMANCE FACTORS

SYSTEM	MISSION	KEY PERFORMANCE FACTOR
AAH	• Provide Aerial Fire Support • Tactical Mobility and Support	• Acquire/Destroy Targets • Survivability
UTTAS	• Squad Carrier • Combat Service Support	• Low Life Cycle Cost • R&M Improvements
ASH	• RSTA/D • Direct Aerial Fire Support	• All Weather Day/Night Capability • Agility
RPV	• Unmanned RSTA/D	• Low Acquisition Cost
CH-47D	• Medium Lift Transport	• Payload • Reliability
HLH	• Transport of Cargo • Retrieval of Equipment	• Capacity • Precision Hover
OV-X	• Intelligence • Electronic Warfare	• Endurance • Payload
SUR/VTOL	• Intelligence • Electronic Warfare	• Forward Area Operation • Penetration Capability
AAWS	• Area and Point Target Suppression • Extended Area Reconnaissance	• Acquire/Destroy Targets • Survivability
LAH	• Armed Reconnaissance • Area and Point Target Suppression	• Survivability • Compatible with ASH
LUH	• Troop Lift • Utility Transport	• All Weather Capability • Compatible with ASH
ITAV	• Observation • Visual Reconnaissance • Command and Control	• Forward Area Operation • Operation/Maintenance Simplicity

respect to their impact on aircraft systems. Such studies are used to identify those areas that appear to hold the highest potential. Gaps in scientific disciplines or supporting technologies are identified. Such studies constitute a major and continuing function of the Laboratories' Advanced Systems Research Office.

During the preparation of the RDT&E Plan, consideration was given to the relevant R&D programs of other Army organizations. In particular, activities have been coordinated in the areas of human factors, avionics, ground handling, and weapons where performance requirements necessitate the integration of these factors into the total airmobile system, but where mission responsibility for appropriate R&D is in another commodity command or corporate laboratory. Moreover, RTL have recognized and maintained an interchange with those organizations that have been designated as "Lead Laboratories" and whose charters encompass technologies important to Army aviation. For example, RTL have activities and interests that relate directly to the work in fluidics at Harry Diamond Laboratory, to the materials research at Army Materials and Mechanics Research Center, and to the efforts of U.S. Army Electronics Command's Night Vision Laboratory in night operations.

The RDT&E Plan clearly indicates that VTOL aircraft technology can expect significant advances over the 20-year time frame, which, in turn, can affect the aircraft systems designed in the 1978-1997 time period. The precise magnitude of technological improvement that can be achieved is governed by other than purely technical considerations, of which the most important are the necessary budgetary and schedule constraints.

The Plan becomes the program when the required resources in terms of funds, facilities, and personnel are provided for its implementation. Even if unlimited resources are available, it is not likely that all the efforts would be pursued and all the goals achieved. Therefore, it would be unrealistic to make an estimate of resource requirements that is based on the development of all the concepts for each of the projected systems. Moreover, the available options and alternatives to perform a given task diminish rapidly with time, so estimates of resource requirements are valid only on a relatively short-term basis. Even more to the point, however, is the fact that there are never enough resources to undertake all of the research projects that optimum planning would indicate; there are generally many more feasible technical alternatives available to solve a particular problem than can be economically supported. Under conditions of limited resources, imposed economics, and prescribed goals, a logical resource allocation methodology is the key to orderly progress. The Laboratories' Project Selection Process was developed to provide RTL management a program selection means based on R&D objectives, priorities, and supporting rationale. This process is described in detail in the RDT&E Plan with application to each of the RTL technology disciplines.

The Advanced Systems Research Office of RTL, under the Aircraft Systems Synthesis Project, directs the development of the Army Aviation RDT&E Plan and is responsible for the development and application of the project selection process (OPR). The OPR procedure is the means to provide Laboratory management with the guidance necessary to tie properly the planning and programming to budgeting.

The development of the Laboratories' Project Selection Process requires

- Clear definition of fundamental laboratory technical objectives,
- Priority of these objectives,
- Rationale supporting the technical thrust (effort).

The budget process is a recurring one in which the RTL and their Headquarters, AVRADCOM and DARCOM are involved. The cycle begins with a five-year funding guidance document, the Command Schedule. Upon receipt of the Command Schedule, the Laboratories prepare proposed programs and plans (AMC Form 1534 – RDTE Program Data Sheet and DD Form 1634 – Research and Development Planning Summary) in response to the guidance document. These programs and plans are then submitted to DARCOM through AVRADCOM for review. Guidance (AMC Form 1006 – Program Directive/Program Change Request) from DARCOM is issued, which constitutes expected funding for the next fiscal year. Proposed programs (AMC Form 1006A – Program Directive/Program Change Request) are then prepared by the Laboratories, detailing specific efforts to be undertaken in view of this guidance. The cycle repeats each fiscal year with the issuance of a new Command Schedule.

To assist in the development of the above AVRADCOM/DARCOM program documentation, each RTL Laboratory provides detailed program planning at the research element unit level. The procedure, identified as RTL Annual Narrative Program (ANP), describes planned activities for a three-year period and provides budgetary information and milestones for a five-year period.

OUTSIDE/INSIDE EXPENDITURES

The distribution of FY77 program funds received by RTL as presented in Table II is categorized under three basic headings: Industry or Academic, other DARCOM Labs, and other Government Agencies, for each of the program categories; i.e., 6.1, 6.2, etc. Within each category, the amount for contract (outside) and the total amount for that category is listed. The ratio (percent) of the outside contract amount to the total amount for each program category is obtained by subtracting the three contract expenditures from the total.

The contract monies under industry or academic institutions include contracted efforts purchased through NASA procurement in direct support of the in-house research efforts at the three Laboratories collocated with NASA Research Centers. In regard to the outside/inside expenditures, Table II, it is important to note that, of the total expenditures in 6.1 and 6.2 categories, $12.4 million or 52.7% was spent in-house. On the other hand, of the total RDT&E money, only $16.5 million or 39.3% was spent in-house.

As R&D efforts progress through exploratory development to advanced development, the hardware required to conduct research increases. This results in an increase both in dollar amount and percentage of contracted work, as reflected in the 6.3 category. The largest portion of these projects is contracted by the Contracting Division at the Applied Technology Laboratory. In most of these cases, the in-house operation costs applicable for contract administration are provided in the estimated cost to administer column, Table II.

The policy of RTL has been to maintain a balance of at least two dollars out-of-house work to one dollar in-house for its entire area of responsibility. This policy does not result from guidelines or constraints from higher level, but rather is considered to be a proper ratio in order to maintain both in-house expertise and responsiveness in the industry that supplies the commodities for the Command. As reflected in Table II, the 6.2 category represents a larger percentage of RTL effort as compared to the 6.3 category. In FY77, 51.4% of RTL direct funds were distributed into the 6.2 category while in FY76/7T the ratio was 44%. The reduction in out-of-house to in-house ratio, due to this change, did not occur as a result of change in policy or a shift in actual funds, rather it is a result of the continuing downward trend in Army Aviation's 6.3 Advanced Development program budget.

It is the policy of the Laboratories to utilize the expertise and specialized capabilities of other DARCOM Labs/Installations to conserve resources and prevent duplication of effort in accomplishing the RTL mission. During FY77, a total of $2.9 million (or 7.9%) of the RTL direct program funds were distributed to the DARCOM Labs/Installations shown in Table III. It is the intent of the RTL management that the above policy continue into the future.

ACCOMPLISHMENTS

PROGRAM BALANCE

The program structure for RTL in FY77 by funding allocations is reflected in Table IV. The total RTL funding for the Army Aviation R&D Program, including reimbursable orders amounts to $43.0 million, is a small percentage of the Army's total RDT&E budget, and even smaller in comparison with the total resources expended for airmobile systems development and procurement.

TABLE II. FY77 OUTSIDE/INSIDE EXPENDITURES (AS OF 30 SEP 77)

TOTAL LAB EFFORT	INDUSTRY AND ACADEMIC			OTHER DARCOM LABS			OTHER GOVERNMENT AGENCIES			ESTIMATED COST TO ADMINISTER*	
	Contract	Total**	Ratio	Contract	Total**	Ratio	Contract	Total**	Ratio		
RDTE FUNDS	$K	$K	%	$K	$K	%	$K	$K	%	$K	%
6.1 Research	1414	4635	30.5	0	4635	0	0	4635	0	115	2.5
6.2 Exploratory Development	9273	18949	48.9	241	18949	1.3	217	18949	1.1	2019	10.7
6.3 Advanced Development											
6.3a	10560	13277	79.5	4	13277	0	11	13277	0	1067	8.0
6.3b	3204	3798	84.4	1	3798	0	2	3798	0	183	4.8
6.4 Engineering Development	492	693	71.0	0	693	0	0	693	0	98	14.1
6.5 Mgt & Support	60	639	9.4	0	639	0	0	639	0	0	0
6.7 Oper Systems	0	0	0	0	0	0	0	0	0	0	0
RDTE TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PROCUREMENT FUNDS											
DARCOM	512	616	83.1	0	616	0	0	616	0	22	3.6
Non-DARCOM (Other Army)	0	0	0	0	0	0	0	0	0	0	0
Non-Army	0	0	0	0	0	0	0	0	0	0	0
PEMA TOTAL	512	616	83.1	0	616	0	0	616	0	[illegible]	[illegible]
OMA FUNDS											
DARCOM	224	320	70.0	0	320	0	0	320	0	18	5.6
Non-DARCOM (Other Army)	0	50	0	0	50	0	0	50	0	0	0
Non-Army	0	0	0	0	0	0	0	0	0	0	0
OMA TOTAL	224	370	[illegible]	0	370	0	0	370	0	18	[illegible]
GRAND TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*Total expenditure for each line; i.e., 6.1, 6.2, etc.
**In-house cost for purely administrative duties, both technical and managerial.

TABLE III. DARCOM LABS/INSTALLATIONS USED BY RTL

DARCOM LABS/INSTALLATIONS	PURPOSE
ARMY MATERIAL & MECHANICAL RESEARCH CENTER	• Research in Safety and Survivability • Support in Aircraft Structures
BALLISTICS RESEARCH CENTER	• Research in Safety and Survivability • Weapons Technology – Rocket
MOBILITY EQUIPMENT R&D COMMAND	• Mini-RPV Propulsion
PICATINNY ARSENAL	• Aircraft Weapons Technology
ROCK ISLAND ARSENAL	• Weapons Test Facility
WATERVLIET ARSENAL	• Research on Structures
TRAINING AIDS DEVELOPMENT CENTER	• Simulation Technology
COMBAT SURVEILLANCE & TARGET ACQUISITION	• Mini-RPV Electronics Technology
NIGHT VISION LAB	• Mini-RPV Electronics Technology

The reimbursable program for FY77 totals $6.3 million, a portion of this amount was received from the OMA and PEMA funded programs as shown in Table V.

Joint participation agreements have enabled the Army and NASA to enter into mutually beneficial research and development programs which neither one could afford to pursue alone. Notable among such projects are the developments of the Tilt-Rotor Research Aircraft at Ames Research Center and the Rotor Systems Research Aircraft at Langley Research Center. These programs, along with others, have both military and civil applications and thus, improve the effectiveness of resource utilization on a national basis.

The RTL Funding Summary; Command Schedule, Direct Funding Authority, and Obligational Authority, for the period of FY73 through FY77 is presented in figure 8. With careful planning and management, RTL have obligated no less than 98.0% of its available program funds for each of these fiscal years. The 98.0% obligation rate for each fiscal year exceeds the DARCOM goal of 96%. Continued success in this area depends on careful program management. The delay associated with late releases of funds could result in inability to define explicitly the work to be done and in proposal evaluation which are lacking in proper depth and, hence, could adversely affect the quality of the ultimate R&D product.

The concept of single project/program element funding (SPF/SPEF) has gained significant acceptance since its implementation. However, the advantage of the SPF/SPEF program in providing broad local management flexibility by removing some intra-program element reprogramming restrictions results in a decrease in some individual project visibility at higher levels. As a result, additional reporting requirements have been imposed. It is believed that in order to obtain the optimum benefits from SPF/SPEF, additional reporting should be eliminated or reduced;

TABLE IV. FY77 FUNDING FROM ALL SOURCES

PROGRAM BREAKOUT	SUBTOTAL	TOTAL
RDTE FUNDS		
6.1 Research	4635	
6.2 Exploratory Development	18949	
6.3 Advanced Development	17075	
6.3a 13277		
6.3b 3798		
6.4 Engineering Development	693	
6.5 Management & Support	639	
6.7 Operational Systems	0	
RDTE TOTAL		41991
PROCUREMENT FUNDS (PEMA)		
DARCOM - Hq	0	
- Other	616	
Non-DARCOM (Other Army)	0	
Non-Army	0	
PEMA TOTAL		616
OMA FUNDS		
DARCOM - Hq	0	
- Other	320	
Non-DARCOM (Other Army)	50	
Non-Army	0	
OMA TOTAL		370
GRAND TOTAL		42977

SOURCE BREAKOUT	
DARCOM SOURCE	
Hq, DARCOM	36690
	5225
Other DARCOM Customer	662
SUBTOTAL	42577
Non-DARCOM Customer (Other Army)	
Army Training and Doctrine Command (TDI)	50
SUBTOTAL	50
NON-ARMY	
Navy	350
SUBTOTAL	350
	42977

FUNDS IN THOUSANDS OF DOLLARS
MODE OF FUNDING – APPROPRIATION

TABLE V. REIMBURSABLE PROGRAM

SOURCE	PROGRAM	APPROPRIATION
ARMY		
TRADOC	TDI Support	OMA
AVRADCOM	MM&T	PEMA
AVRADCOM	RPV	RDTE
AVRADCOM	ASE	RDTE
AVRADCOM	SIRS	OMA
AMMRC	Material Scale-Up Demonstration	AIF (RDTE)
BRL	High Energy Laser Components	AIF (RDTE)
HDL	Fluidic Tech Invest	RDTE
TSARCOM	Diagnostic Program	OMA
FSTC	Helicopter Main Rotor Blades	OMA
NAVY	ABC	RDTE

and minimum required information should be generated within the existing budget, accounting, and program reports.

TECHNICAL ACHIEVEMENTS

The principal RTL R&D goal is to maximize mission capabilities and operational effectiveness of Army airmobile systems while minimizing life-cycle costs. The FY77 program for the Laboratories was responsive specifically to DA/DARCOM/AVRADCOM identified goals and objectives as they effect air mobility research and development. Table VI identifies some of the accomplishments of the Laboratories in FY77 that are directly related to these goals and objectives.

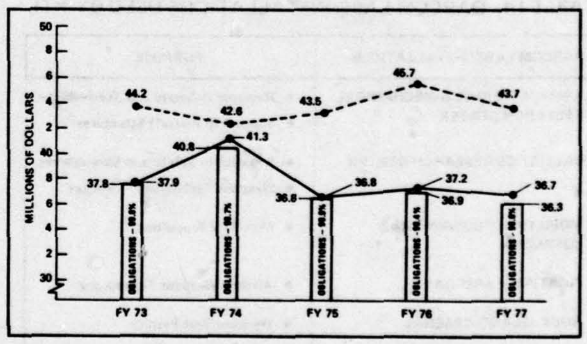


Figure 8. Funding history – FY73-77.

The technological improvement objectives of the FY77 projects were consistent with the near-term objectives identified in the Army Aviation RDT&E Plan of October 1976.

The following summary of significant achievements of RTL during FY78 are presented under the following categories:

- Research – 6.1
- Exploratory Development – 6.2
- Advanced Development – 6.3a

The published output of RTL in terms of in-house and contract activity is documented in Appendix B.

TABLE VI. REPRESENTATIVE FY77 ACCOMPLISHMENTS

SCIENCE & TECHNOLOGY OBJECTIVE	STO REF NUMBER	FY77 ACCOMPLISHMENTS
DEVELOP FIRE & FORGET WEAPONS SYSTEM	77-7.1	• Helicopter airflow phenomena investigated for effect on rocket trajectories. • Terminal trajectory correction investigation initiated. • RPV armament preliminary investigation initiated.
IMPROVE HELICOPTER SURVIVABILITY	77-7.2	• Increase ballistic protection through: Design of ballistic damage tolerant cross-beam tail rotor. • Improve flight safety through: Continuation of pilot and crew seat development testing. • Reduction of detection through: Development of air mixer concept for exhaust plume IR suppression.
IMPROVE ADVERSE WEATHER MISSION CAPABILITY	77-7.3	• Development of advanced ice protection systems (microwave and vibratory) concept with preliminary design and laboratory tests initiated.
DEVELOP ON-BOARD PASSIVE IMAGING RSTA SYSTEM	77-7.5	• AQUILA Mini-RPV system has progressed to user testing phase. • Technology development of Mini-RPV components is continuing.
DEVELOP IMPROVED EXTERNAL CARGO HANDLING CAPABILITIES	77-7.7	• Completed identification of external cargo carrying concepts for CH-47 and Black Hawk with NOE limitations established. • Gondola system has progressed through design and fabrication and is in Feasibility Demonstration Test Evaluation phase.
DEVELOP EFFECTIVE SHIP-TO-SHORE CARGO DELIVERY SYSTEM	77-7.8	• Feasibility of Container Lift Device for acquiring, transporting and delivering MIL-Van containers without ground support has been demonstrated.
REDUCE HELICOPTER LIFE CYCLE COSTS	77-7.11	• Continuation of technology and concept development to reduce life cycle costs in all technical disciplines with emphasis on: Performance Propulsion Reliability and maintainability.
DEVELOP ADVANCED STRUCTURAL MATERIALS	77-7.12	• Development of advanced composite structure for rotors and airframe for reduced vulnerability to hostile environment.
REDUCE ROTARY-WING PILOT WORKLOAD	77-7.13	• Determination of visual, motion, and human engineering research requirements for integration into flight simulator program is continuing.
IMPROVE MAN-MACHINE INTERFACE	77-7.16	• Demonstration of kinesthetic-tactual display for helicopter cyclic and collective controls conducted by Army pilots.
VEHICLE/MISSION SIMULATORS	77-7.17	• Simulator requirements for man-in-loop simulation of helicopter flight in day/night all-weather NOE defined. • Development of R&D simulator capability continuing.

AIR MOBILITY-PROGRAM CATEGORY 6.1

RESEARCH IN AERODYNAMICS

A detailed understanding of the aerodynamics of helicopters is particularly difficult to achieve because of the complex time-varying flow field in which a helicopter rotor operates. Helicopter performance, aeroelastic stability, vibration, static and dynamic loads, handling qualities, agility and acoustic signature are all directly related to the nature of the helicopter aerodynamic flow field.

2-D Airfoil Sections – The major efforts in airfoil section development have traditionally been oriented toward fixed-wing aircraft applications. The unique flow field of the helicopter rotor requires a different set of airfoil characteristics than those desirable for fixed-wing aircraft. Significant progress has been made toward development of a technology for improving airfoil section aerodynamic characteristics for helicopter applications. Two-dimensional wind tunnel tests of industry and government-developed airfoils were conducted and results disseminated at the airfoil workshop which has been established to expedite information exchange. Tests included five industry and four government-developed airfoils. In support of the AAH SSEB, 2-D wind tunnel tests and analytical evaluations were made of a baseline and a proposed alternate airfoil for one of the competitive vehicles. In addition, the effects of Reynolds number on 2-D characteristics of four rotorcraft airfoils have been investigated and results are being used to evaluate and improve the validity of scale-model testing. Tests and analyses have also been conducted to evaluate a series of government-developed airfoils which are designed to improve utility helicopter performance. These airfoils are based on analytical design criteria and change as a function of rotor radial station. Preliminary results indicate higher drag divergence Mach numbers than on other airfoils of comparable thickness and show favorable lift and pitching moment characteristics. Figure 9 shows a test airfoil in the 6- by 28-Inch Transonic Wind Tunnel.

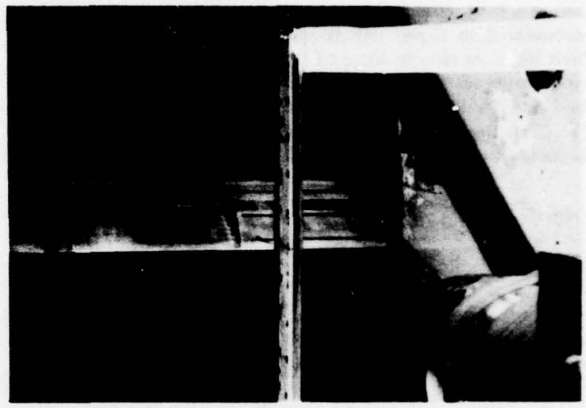


Figure 9. Test airfoil in 6- by 28-Inch Transonic Tunnel.

Rotary-Wing Airfoil Dynamic Stall – During maneuvers at high forward speed conditions, large unsteady airloads are applied to the rotor blade because of dynamic stall of the retreating blade. This phenomenon has been investigated by means of wind tunnel tests of properly scaled sinusoidally oscillating airfoils. This research has demonstrated the true nature of the boundary layer separation mechanism in causing dynamic stall. The goal of this research is to supply a satisfactory dynamic stall load prediction method for the helicopter industry. An associated objective is to identify the process by which dynamic stall is initiated, and from this, develop a technique for modifying the dynamic stall. Theoretical analysis efforts are directed at extending computations for incompressible potential flow about a steady airfoil to produce exact solutions for arbitrary incidence angles and extensions, in order to provide compressibility corrections and potential application of unsteady corrections. Experimental efforts are proceeding in several areas. Fabrication of models for sinusoidal unsteady testing of six currently used helicopter rotor airfoils has been completed. These airfoils will be tested in the Ames 7- by 10-Foot Wind Tunnel in FY78 to measure the dynamic stall characteristics of these advanced sections. In a related effort, an operational demonstration at the Pitch Rig in the Langley Transonic Dynamics Tunnel has established the capability of helicopter rotor blade dynamic stall research at realistic Mach numbers. The Pitch Rig, as shown in figure 10, accommodates airfoil models up to 6 ft in span and 26 in. in chord. The diamond-shaped boxes contain rotary hydraulic actuators that set the mean angle of attack (up to 20°) and drive the blade in pitch about the quarter chord point.

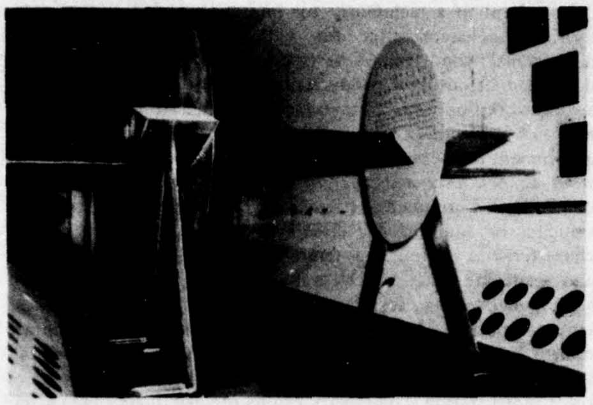


Figure 10. Pitch rig in Transonic Dynamics Tunnel.

The test used a CH-54B blade section. Operation over the design envelope, 30 Hz at 12° peak to peak oscillation with a fully-stalled airfoil, was achieved. The capability to reproduce any waveform in this envelope, either sinusoidal or a simulation of oscillations encountered in flight, will be possible. Another feature of the Pitch Rig is to remove some of the limitations of low-aspect-ratio wind tunnel tests. By using freestanding endplates, independent of the tunnel walls, aspect ratios from one to five can be explored. The Pitch Rig will also allow testing of full-scale blades at realistic Reynolds numbers and up to 0.5 Mach number.

Helicopter Missile Pod Drag – In support of the AAH SSEB, full-scale wing/pylon and two missile configurations for each of the two AAH aircraft were conducted in the V/STOL tunnel. The objective of the program was to establish actual drag values for each configuration in order to obtain valid performance assessments of each proposed aircraft and to investigate the feasibility of drag reductions on the HELLFIRE missile systems, figure 11.

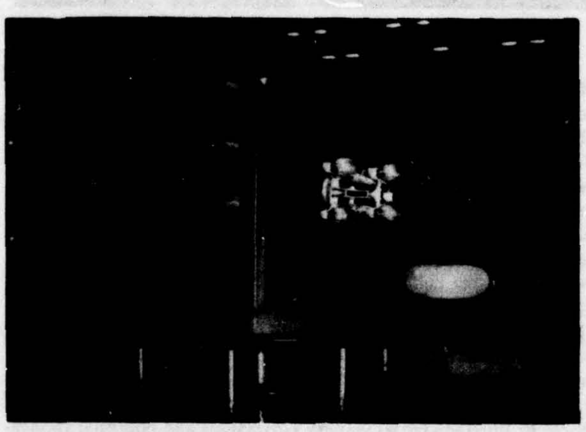


Figure 11. Helicopter missile pod drag test for HELLFIRE.

Subsequently, full-scale wind tunnel investigations were conducted to evaluate means of reducing the drag on the M200A1 and HELLFIRE rocket launcher systems. With incorporation of a ring-cowl on the nose of the M200A1 pod, parasite drag reductions of 80% were demonstrated. In support of the HELLFIRE and YAH-64 Project Offices, wind tunnel tests were conducted to demonstrate the modifications which are necessary in order to reduce the HELLFIRE launcher drag to less than 1.2 sq ft.

Aeroelastic Stability Analysis – Dynamic stability of rotors, in general, and hingeless rotors, in particular, need more detailed understanding of basic phenomena. Consideration is being given to stability of the isolated rotor blade, mounted on a fixed hub, and to stability characteristics of the coupled rotor-bodied systems. For the isolated rotor blade, analyses include simplified rigid-blade representations, as well as more elaborate uniform and non-uniform elastic-blade models. The work emphasizes low frequency stability characteristics in hovering flight, where structural coupling phenomena of bending and torsional motions can be important. This result is especially true for advanced bearingless rotor configurations. The Flex Beam Air Resonance (FLAIR) program has been used to predict stability characteristics for the Bearingless Main Rotor (BMR), and analytic results have shown excellent agreement with model tests conducted at Boeing Vertol. Figure 12 shows the comparison of FLAIR analysis results with wind tunnel data in the prediction of air resonance stability as a function of rotor RPM for a BMR test configuration. This program has been provided to the helicopter industry and is being used in their IR&D programs. Together, the FLAIR program and the Program Rotor Body (PRB) analysis provide a very good capability to determine rotor sensitivities to instabilities. They also provide a physical understanding and the detailed analysis required to predict rotor stability boundaries.

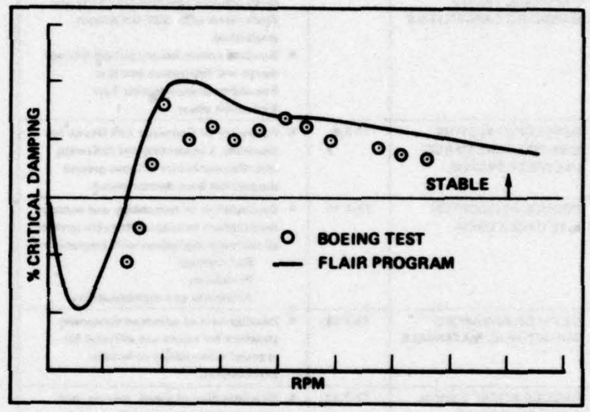


Figure 12. Air resonance stability vs. rotor speed for 1g flight.

Acoustic Measurements – The major effort required this year was to make noise measurements in conjunction with the acoustic evaluation of both the UTTAS and AAH competitor aircraft. In addition to providing direct support to the UTTAS and AAH PMs, the data obtained provided an excellent data base for comparison with theoretical work which has materially advanced the understanding of rotor acoustic properties and mathematical modeling of acoustic phenomena. The primary data in these tests were taken in flight, using the upgraded In-Flight Far-Field Impulsive Noise Measuring Concept. A YO-3A quiet airplane, with microphones installed on the wing tips and the vertical tail, was flown in formation with the test aircraft as shown in figure 13. Data were

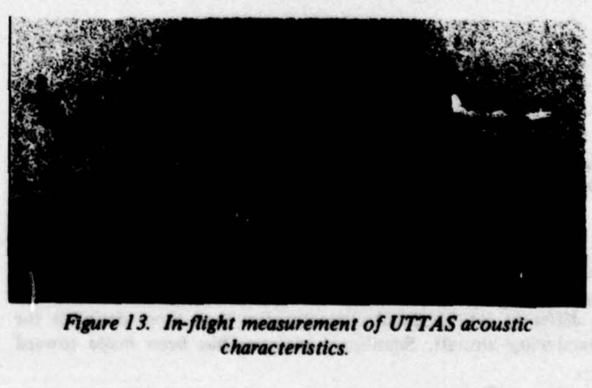


Figure 13. In-flight measurement of UTTAS acoustic characteristics.

taken at different positions relative to the test aircraft over a full range of operating conditions. Ground measurements were taken to provide additional information which will now be examined for further insight into acoustic phenomena, test procedures, and acoustic signature reduction techniques.

RESEARCH IN PROPULSION

This project consists of basic research, conducted jointly by the Propulsion Laboratory and the Lewis Research Center of NASA, aimed at advancing the technology of propulsion and drive train components and systems. The work is directed toward the solving of special problems involved in the development of small gas turbines (airflow less than 20 lb/sec), and the investigation of advanced concepts in mechanical devices employed in drive trains.

Compressors – Performance reports have been published on a 6:1 conventional backswept impeller with vane and vaneless diffusers and on a 6:1 tandem bladed impeller with cascade and vaneless diffusers (NASA TM X-3552 and TP1091). The tandem bladed impeller is shown in figure 14. Several diffusers have been designed for use with the conventional impeller to determine the effect of diffuser parameters on range and efficiency. Progress is continuing on the development of theoretical 3-D viscous flow solutions for centrifugal impellers. A solution has been obtained for an 8:1 impeller on planes normal to the streamlines to complement a previous blade-to-blade solution. The results are being analyzed to determine the direction of further research.

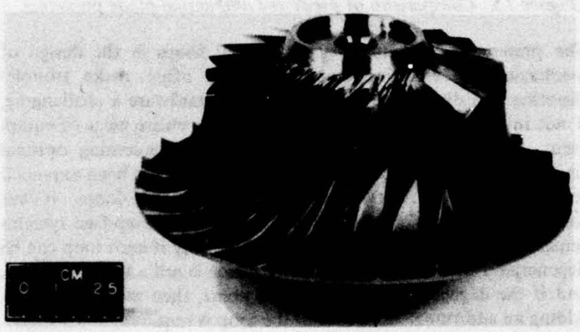


Figure 14. Research 6:1 backswept tandem bladed impeller.

Combustors – In-house programs underway include investigations of liner cooling techniques, effect of wall and boundary layer temperature on premixing fuel and air, and methods of varying geometry to maintain optimum airflow split between primary and dilution zones over wide power ranges.

Turbines – Part of an in-house program to improve the predictability of cooled blade and vane metal temperatures and performance was reported in NASA TP1036. Testing of a 6-in. radial turbine with thick blades to allow for internal cooling is underway. Aerodynamic design of a 5-in. axial turbine with a contoured end wall stator is about 75% complete.

Materials – Current in-house research results on materials technology were reported in NASA TM X-3429, NASA TM X-73,586, NASA TN 8383, and NASA TM X-73,591. Current research efforts to improve the impact resistance of silicon nitride and silicon carbide has demonstrated impact strengths in excess of 20 in./lb; the program goal was 12 in./lb. Research is continuing to obtain consistent, thermally stable results. A program has been initiated on a new concept for producing pressureless sintering of silicon-nitride shapes. In-house work directed at improving the technology of transmission, engine, and turbine tip seals is underway.

RESEARCH IN STRUCTURES

Research in the aircraft structures technology base is, primarily, committed to developing new ways of safely and economically transmitting loads throughout an aircraft with minimum weight penalty. The effort is largely one conducted by the Structures Laboratory, with support from Watervliet Arsenal.

Analytical Techniques for Complex Structures – The RTL have continued to participate in IPAD development. This computer system, being developed under a NASA funded contract with The Boeing Company, is designed to handle the information processing requirements of aerospace design and manufacturing interface. Tasks to define the baseline aerospace design process and manufacturing interfaces are essentially complete, and conversion of the results into information processing requirements is underway.

Research is being conducted to determine the feasibility of using minicomputers for graphic support and data base manipulation. This research has shown that the minicomputer can be a cost effective tool for interactive graphic support for engineering analysis and design. In addition, research is being conducted on the feasibility of building a specialized minicomputer/microprocessor for use in finite element analysis. The approach has been to decompose the finite element method of structural analysis into kernels of parallel activities and determine if selected functions can be done more effectively with especially tailored computer hardware. A paper reporting the potential application of microprocessing to finite element analysis has been presented at the ASME winter meeting.

Fatigue and Fracture Mechanics – During the past year research was focused primarily on fatigue of laminated composite materials. The objective of the research was to develop a realistic fatigue model which could be used both to predict composite fatigue behavior under realistic service conditions and to improve composite laminate designs. A fundamental step in the development of a fatigue model was to determine the complicated fatigue process in composite laminates. Recent results showed that the fatigue process in boron/epoxy laminates was triggered by matrix degradation in off-axis plys, followed by fiber breaks in those plys, and finally failure of the load carrying plys. As a parallel effort, the significance of environmental factors of fatigue of laminates was being studied. A unique outdoor fatigue testing facility was put into operation and laminates were tested in real time under realistic spectrum loadings in an outdoor environment. As of this date three thousand real-time aircraft flights have been simulated. Results of this study will be used to make the proposed fatigue model as realistic as possible. In addition, research to predict fatigue behavior of metal systems that were reinforced with composite materials was being conducted. Results of this effort are forthcoming.

In the fatigue of bonded joints program, three areas of progress have been made. The initial work was reported in NASA TN D-8126. This work showed the relationship between strain energy release and cyclic debond rate for different adhered thicknesses, elastic moduli, stress ratios, and type of adhesive. An SEM analysis of the failure surfaces was also given. The second area of progress has shown that the "peel-ply cloth" used to facilitate handling of composite laminates can cause an order of magnitude difference in the cyclic debond rate. This work is continuing with the aid of the Lockheed-Georgia Company. The third area of progress concerns the modification of an advanced version of the

finite element program used to determine the state of stress in bonded joints. This computer program has the capability of analyzing the stress field under thermal loading and of changing the boundary conditions at the failure surface. With this analysis we expect to determine which local stress, peel or shear stress, is the principal mechanism causing cyclic debonding. This work will aid us in designing better fatigue resistant joints.

Advanced Materials Application to Helicopters – The bearingless rotor concept offers significant improvements over conventional articulated rotors in maintainability, reliability, and structural efficiency, by eliminating critical bearings in the rotor hub. The use of composite materials may provide a breakthrough in the development of bearingless rotor concepts. Composite materials provide the necessary axial strength and stiffness for rotor blade spars and yet can be easily twisted to attain different blade pitches. Although composites have been used and verified for bearingless tail rotors, their use in main rotor spars has not been verified. A joint Army/NASA program has recently been completed which included the design, fabrication, and fatigue test of critical components in a composite bearingless main rotor system. The program involved full-scale and half-scale test of critical components such as the hub and blade attachment fittings.

One of the present drawbacks to composite applications to helicopter structures is the lack of a solid history of successful flight service experience as a guarantee against unanticipated material problems. The only remedy is to put a composite secondary structure into extended flight service use and monitor it for unforeseen problems. One application that characteristically sees particularly severe treatment is the cargo loading ramps on CH-53 and CH-47's. The skin material frequently is in contact with rocky and uneven terrain during heavy cargo loading operations and is often penetrated and later repaired or replaced. For this reason a Kevlar aft skin is being installed in a CH-53 which will be returned to regular service during this year. The present plans call for five years of regularly scheduled inspections at decreasing frequencies.

A testing program of 1/4 diameter fasteners in Graphite-epoxy composites was completed with the final report, CR-144899. An in-house test program of 7/16 and 5/8 diameter fasteners in Graphite-epoxy has also been completed. These test specimens had similar E/D and W/D ratios to the 1/4 diameter holes specimens, to determine the effect of scale up in fastener size on the joint strength. Results are currently being analyzed.

RESEARCH IN MATHEMATICS

The basic mathematical research efforts of RTL are directed, *primarily, to the general domain of aerodynamics,* propulsion, structures, and design analysis. The end results of these efforts contribute to filling the technological needs and requirements of advanced airmobile systems. Mathematics and computers are daily tools used in R&D efforts. The RTL program on mathematical sciences and computing includes research in applied analysis, parallel computation, decision risk analysis, and preliminary design computational methods.

Applied Analysis – a general two-dimensional ADI scheme for solving the unsteady transonic small disturbance equation has been developed and used to compute some high speed rotor flows. Good comparison with experimental rotor data has been achieved. A similar two-dimensional code, using a variable artificial time step, has yielded a very fast means to obtain steady solutions. The result was presented at the Second European Conference on Rotary Wing Aircraft and Powered Lift. Also, this ADI scheme has been extended to obtain three-dimensional unsteady non-lifting solutions. The results compare favorably with those of a recent experiment which established the spatial and temporal pressure distribution on a model rotor. Figure 15 illustrates a typical comparison of predicted and actual blade pressures.

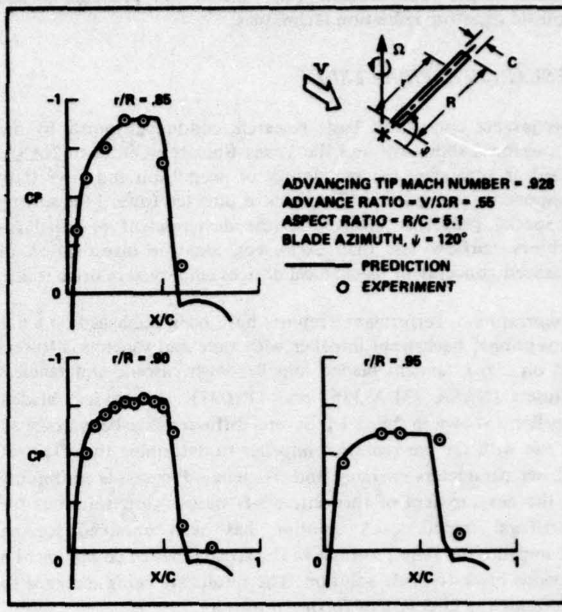


Figure 15. Comparison of predicted and actual blade pressures.

The presence of feedback or functional loops in the design of mechanical or electrical equipment can often make trouble-shooting and diagnosis of malfunctioning hardware a challenging, if not impossible, task without replacing the entire piece of equipment. A theorem established during FY76 concerning optimal fault detection technique for loop-free systems has been extended to cover physical systems containing functional loops. It was found that the conclusions of the theorem for loop-free systems remain valid for systems containing loops, only if each loop can be degenerated into a functional entity which is not a terminal point; and if the degeneration is a terminal point, then modification by adding an additional test point in the loop is required.

Decision Risk Analysis – Source selection process evaluates competitive proposals for a development program. If a particular developmental program is of high risk, then one technique to reduce the risk and assure a better chance for program success is to award multiple contracts for parallel developments. Of course, the immediate effect is the increase in development costs to fund the multiple sources. The key question is how one should approach the problem in deciding whether or not multiple developments should be pursued. If the answer is affirmative, the next question is how to choose the contractors. The former question is a managerial problem concerning time and fund constraints. The latter question must establish the optimum number of contractors and determine which contractors are worthy of consideration. A mathematical treatment of the latter question has been completed, and the existence of an optimal solution to the two-contractor source selection has been established.

AERONAUTICAL TECHNOLOGY – PROGRAM CATEGORY 6.2

AERODYNAMICS TECHNOLOGY

The Laboratories' effort in exploratory development of aerodynamics follows the 6.1 technology subdisciplines of fluid

mechanics, dynamics, flight control, and acoustics and is conducted by the Aeromechanics, Applied Technology, and Structure Laboratories.

Blade Tip Planform Effects on Hover Performance – As the performance spectrum of the helicopter has been expanded, several advanced rotor tip shapes, such as the Ogee tip and the swept tip, have been developed experimentally. Previous analytic techniques based on lifting line and momentum theories are incapable of accounting for the effect of advanced tip shapes on rotor performance. An analytic technique for hover performance prediction based on lifting surface theory has been developed, a step which should provide a considerable improvement in prediction capability for rotors with advanced tip shapes. The lifting surface hover analysis features a user-specified panelling or a program-generated cosine panel spacing. The wake may be prescribed, fully relaxed, or an initial calculation of the inner wake sheet with further calculation iterations on the tip vortex. Curved line vortex elements are used. Compressibility and boundary layer effects are included. A simple aeroelastic model is used for blade bending and twisting. Figure 16 shows the features of the lifting surface hover analysis.

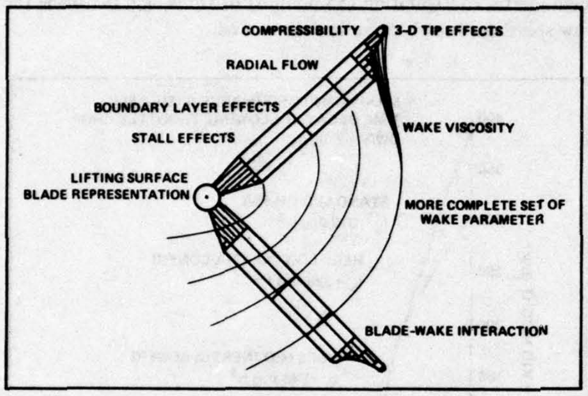


Figure 16. Features of the Lifting Surface Hover Analysis.

Investigation of Flow Separation Models for Helicopter Applications – An analysis procedure capable of predicting two- and three-dimensional aerodynamic characteristics of helicopter fuselage configurations having separated flow regions has been developed. The general analysis procedure consists of a potential flow calculation, a boundary layer analysis, and a model of the separated flow. The analysis begins with the creation of planar surface panels from fuselage cross-section data input by the user. The inviscid flow field about this configuration is determined by the potential flow program. A series of streamlines are then calculated over the configuration surface, providing information required for the boundary layer methods. Laminar, transition, and turbulent boundary layer characteristics (including the separation point, if separation is present) are determined along each streamline, as are the source distributions representing the attached flow viscous effects. The separation points are used to map the separated flow region on the configuration geometry from which the vorticity shear layer leaves the surface. A new potential flow calculation is made with the inclusion of both the separation model and the boundary layer sources. The result is a predicted pressure field for the entire body of attached and separated flow.

Interactional Aerodynamics for Single Rotor Helicopters – In 1975 a wind tunnel test program was conducted in the Boeing-Vertol 20-Foot V/STOL Wind Tunnel on a 1/5th-scale UTTAS model (figure 17) to investigate and find solutions for several aerodynamic problems encountered during the UTTAS flight-testing. Specifically, these tests focused upon the structure of the hub/rotor wake in the vicinity of the empennage, the formation of the ground vortex and its relation to hub loads and fuselage loads during transition, and the occurrence of vibratory air pressures from the blade passing over the fuselage. Only portions of the wind tunnel test data were reduced and analysed during the flight-test program of the Boeing-Vertol UTTAS aircraft.

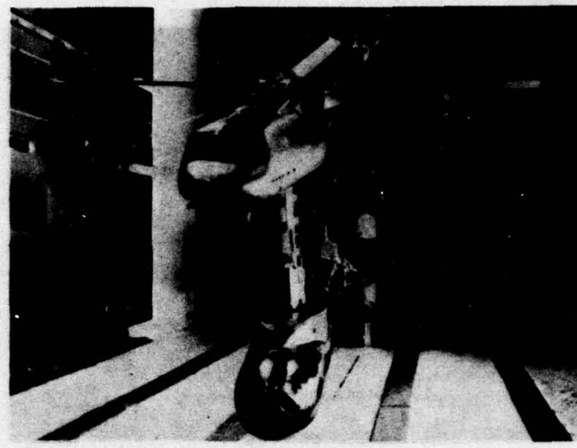


Figure 17. UTTAS model tested in V/STOL Wind Tunnel.

A program is underway to complete the analysis of the data to understand more completely the aerodynamic interactions that are involved and to formulate instructions for the guidance of designers with respect to these interactions. The results of these studies will be applicable to existing and future single rotor/tail rotor helicopters. The data have been segregated according to aerodynamic interactions and associated phenomena/problem areas. These are shown in figure 18, with a listing of the key variables that have been exercised. From this body of knowledge, a generalized set of design guidelines meaningful to the single rotor helicopter concept formulations will be developed.

INTERACTION LOOP	PROBLEM ANALYZED
ROTOR/GROUND	• Formation of ground vortex • IGE main rotor power • IGE hub forces and moments
ROTOR/FUSELAGE	• Vibratory pressures • Fuselage loads • Rotor power
ROTOR/FUSELAGE/GROUND	• IGE fuselage download • IGE fuselage pressure
ROTOR/EMPENNAGE (TAIL ROTOR, PYLON, AND STABILIZER)	• Pressures on stabilizer and pylon • Wake structure • Wake-induced loads • Tail rotor/main rotor blade • Proximity effects
ROTOR/EMPENNAGE/GROUND	• IGE trim change

Figure 18. Interactional aerodynamics for single rotor helicopters.

Full-Scale Rotor Testing – Two rotor tests have been performed in the Ames 40- by 80-Foot Wind Tunnel using the Rotor Test Apparatus. The first of these rotors was a Multicyclic Controllable Twist Rotor (MCTR). This rotor system uses an aerodynamic control surface located on the outboard section of a torsionally-soft rotor blade to vary the twist of the blade collectively and cyclicly. The multicyclic concept varies the twist at frequencies above the primary rotor frequency to provide beneficial higher harmonic loading conditions on the blades. The tests showed that the MCTR has the potential to substantially reduce blade stresses and vibratory loads.

The second rotor tested was an advanced four-bladed rotor system designed and built by Sikorsky Aircraft. This rotor system provided for operation with various rotor tip planforms. Four tip shapes were tested, and data obtained from these tests will be released in mid-1978 in accordance with a previous agreement with Sikorsky. Figure 19 shows the Sikorsky advanced rotor system in the tunnel.

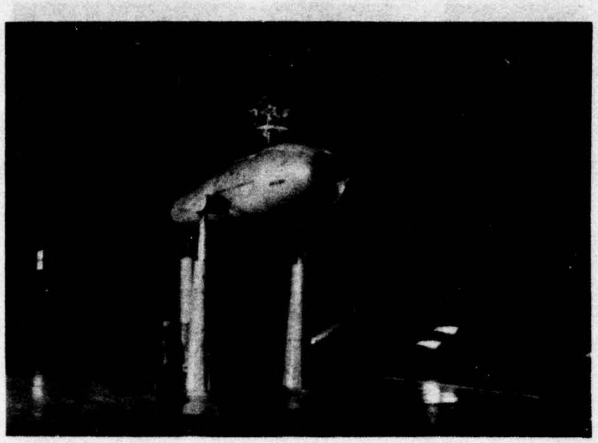


Figure 19. Sikorsky advanced rotor system in Ames 40- by 80-Foot Wind Tunnel.

Ogee Tip Testing – The Ogee tip concept involves a variation in rotor blade tip planform to diffuse the rotor blade tip vortex, as shown in figure 20. Diffusion of the tip vortex may be desirable for reducing noise and loads due to blade vortex interaction, and, for some blade and aircraft configurations, result in an improved loading distribution and improved performance. Full-scale tests of a rotor with Ogee tips were conducted to investigate their effect on acoustics, performance, and loads. Both whirl tower and flight tests of a modified UH-1H rotor were accomplished. The test matrix for hover on the whirl tower included rotor thrust values from 0 to 10,000 pounds at various tip Mach numbers for both standard and Ogee tip rotors. Flight testing on the UH-1H covered the major portion of the flight envelope for that aircraft. Near-field acoustic measurements as well as far-field layover data were obtained for both the Ogee and standard rotors. Analysis of the whirl-tower test data shows that the Ogee tip does significantly

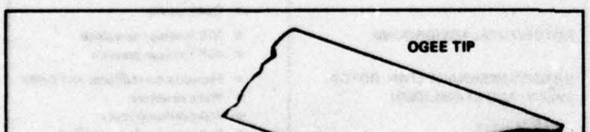


Figure 20. Rotor blade tip shapes.

diffuse the tip vortex. Flight testing of both rotors indicates that the strong impulsive noise signature of the standard rotor can be reduced with the Ogee tip. Forward flight performance was significantly improved with the Ogee configuration for a large number of flight conditions, and rotor control loads and vibrations were reduced. Full-scale tests are continuing on high-performance aspects of the Ogee tip rotor and of a modified Ogee tip rotor.

High Energy Rotor Systems – The High Energy Rotor System (HERS) program has provided data for the study of the effect of rotor inertia on flight safety, performance, and control; the reduction or elimination of the height-velocity operating restriction (deadman's curve); simplification of autorotation landings; and improvement in nap-of-the-earth maneuver performance. An OH-58 was used as a test bed at Bell Helicopter Textron. Standard OH-58 rotor blades were modified by installing 55 pounds of tip weight per blade and adding blade stiffening with a 3-inch trailing edge extension and stiffener plates along the quarter chord. Tip weights were removed for testing of alternate inertias. The results of extensive height-velocity autorotation testing are shown in figure 21, including comparison with the standard OH-58. In the high inertia configuration (55 pounds) of tip weight per blade the low speed deadman's curve was eliminated.

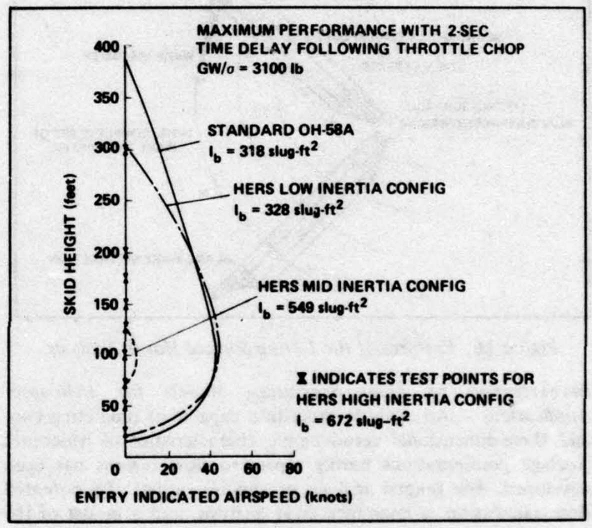


Figure 21. Height-velocity profile.

STRUCTURES TECHNOLOGY

The 6.2 research and development effort in Structures Technology encompasses improving load prediction and analysis methodologies; considering both internal and external loads; improving structural design criteria, manufacturing methods and testing techniques, with a particular focus on the advanced composite materials; and applying these advanced materials and structural concepts to helicopter components.

Rotor Blade Dynamic Response and Ballistic Damage Survivability – The Applied Technology Laboratory is conducting a program with Bell Helicopter to develop an analysis methodology for evaluating the effect of ballistic damage to the helicopter's main rotor blades, up to and including 23 mm HEI-T projectiles. Designing the helicopter main rotor blade to survive this threat has been a desired objective in several of the Army's recent blade development programs; but up to the present, the methods employed to achieve this objective have been largely empirical

ones, based on the results of ballistic tests. The current program consists of four major tasks:

- The development of the analytical tools to perform ballistic, dynamic, and structural analysis.
- The application of this analysis in existing helicopter configurations.
- The experimental verification of the analysis through ballistic and structural tests.
- The development of a ballistic survivability design guide.

The basic analysis methodology developed for this program is referred to as the helicopter Survivability Model (SURVIV). SURVIV is a workable tool that can be used to predict the 23 mm HEI-T ballistic damage to a rotor blade, the dynamic response of the rotor system and helicopter as a result of this damage, and the residual structural strength of the blade. This model enables the designer to compare the merits of competing blade designs on the basis of ballistic survivability. SURVIV has been used to analyze the AH-1G helicopter for main rotor blade damage from a 23 mm HEI-T projectile impact. Both the Bell Helicopter Textron (BHT) 540 metal blade and the Hughes Helicopters multi-tubular spar (MTS) composite blade have been examined.

Finite Element Analysis for Complex Structure – This research program was conducted between the Applied Technology Laboratory and Boeing Vertol to develop and demonstrate a comprehensive finite element technique using NASTRAN to determine the operational characteristics of a helicopter transmission housing. The technique developed can be used to improve and optimize the design of housings made of metal and/or composite materials. A CH-47C forward transmission housing was utilized to investigate stress and deflection due to static and dynamic loads, load-path definition, dynamic response, thermal distortion and stress, and design optimization by the control of structural energy distribution. The analytical results were correlated with test data and were used as a design tool in developing a concept that reflected reduced weight and improved strength, service life, failsafety, and reliability of the transmission housing. The finite element model of the transmission housing used for this work is depicted in figure 22. A preprocessor program (SAIL II) was used for the automatic generation of grid point coordinates and structural element connections. Work under this program was completed in FY77. This NASTRAN technique is being utilized in the conduct of a follow-on Applied Technology Laboratory and Boeing Vertol program.

Composite Main Rotor Hub – The Army's efforts to reduce helicopter costs and to exploit the benefits of structures made from composite materials have resulted in the design, fabrication, and testing of a rotor hub constructed from composite materials in a program conducted between the Applied Technology Laboratory and Kaman Aerospace. Although helicopters of all weight classes should benefit from composite rotor hubs, the need is greatest for large helicopters where the size of a conventional hub approaches the limits of forging feasibility. Accordingly, a graphite-epoxy main rotor hub was designed, using the CH-54B as a baseline (see figure 23). The hub configuration consists primarily of an upper, a pan-shaped middle, and a lower plate, which are graphite epoxy with quasi-isotropic fiber orientation (60/0/60). Together, they provide high structural efficiency, since major loads are transmitted primarily by in-plane direct stresses and shears; high failsafety and ballistic survivability due to diffuse and redundant load paths; ease of inspection for detection of damage;

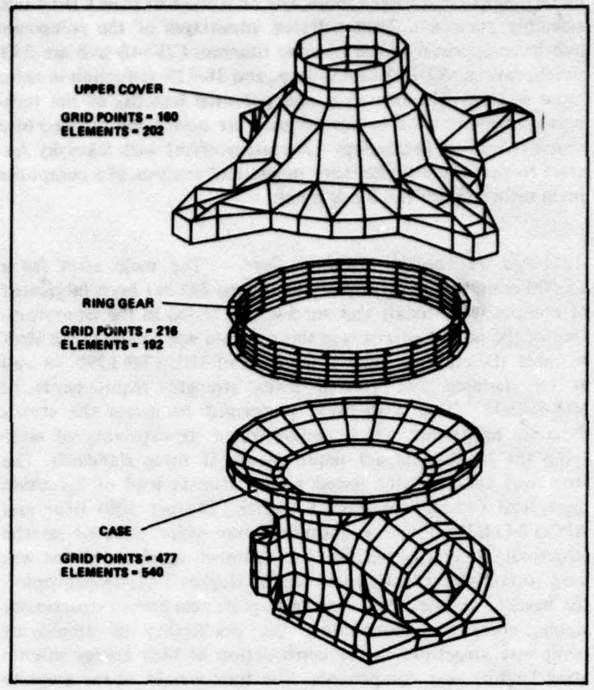


Figure 22. Finite element model of the CH-47 forward rotor transmission housing.

and ease of reliable fabrication. Structural analysis and experimental verification have substantiated the structural efficiency and damage tolerance of the composite hub. Static and fatigue tests were performed to demonstrate strength and stiffness both on a series of composite plate element specimens containing typical

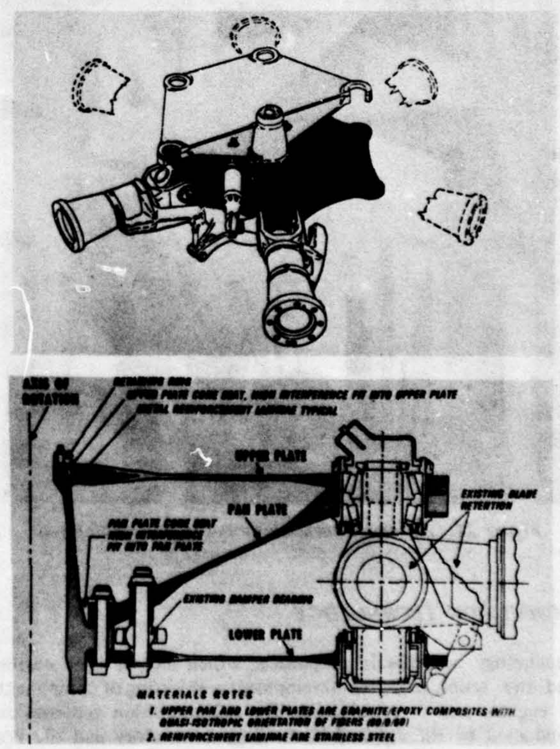


Figure 23. CH-54 composite plate main rotor hub.

metal laminate reinforced joints and on a one-half scale CH-54 hub assembly specimen. Demonstrated advantages of the composite hub in comparison to the baseline titanium CH-54B hub are 24% weight savings, 52-78% cost savings, and 38-93% reduction in radar cross section. The relevancy and potential benefits of the technology demonstrated in this program are now being pursued by a current Applied Technology Laboratory effort with Sikorsky Aircraft to perform a preliminary design and analysis of a composite main rotor hub for the Black Hawk.

Advanced Technology Landing Gear – The main strut for a 15,000-pound class helicopter (see figure 24) has been fabricated of composite materials and successfully tested in the laboratory. One of the prime objectives in this program was to design the strut to meet the crashworthiness standards of MIL-STD-1290, as well as the landing and ground loads strength requirements of MIL-S-8698. Drop tests were performed to assess the strut's dynamic properties, which demonstrated its capability of satisfying the landing impact requirements of these standards. The strut was subsequently tested to an ultimate load of 2.1 times limit load (44,000 pounds). Graphite (Thornel 300) fiber and APCO 2434/2340 epoxy resin/hardware were selected as the structural materials, and the wet filament winding process was used to fabricate a trailing arm for the Hughes YAH-64 helicopter, the baseline vehicle. The resulting graphite arm proved structurally viable, thereby demonstrating the practicality of employing composite structures in the construction of high energy attenuating landing gear components. The final weight of the graphite trailing arm proved to be 7% lighter than the baseline steel arm, but an estimated weight savings of 25% could be expected if a special winding machine were to be developed for fabricating the composite strut.

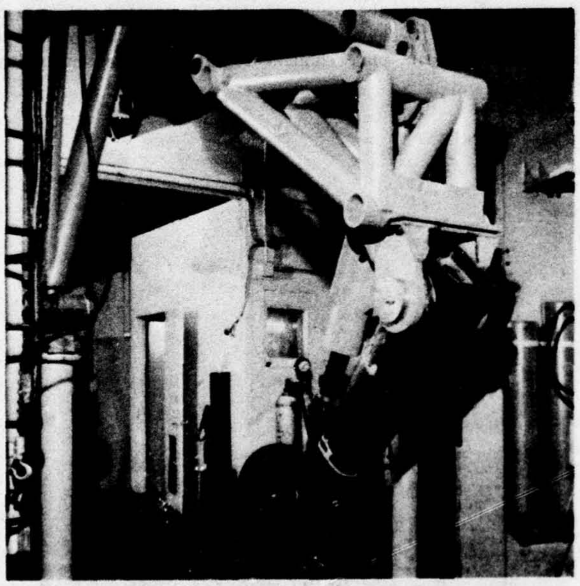


Figure 24. Advanced technology helicopter landing gear.

PROPULSION TECHNOLOGY

Technology activities in propulsion, which include both engines and drive trains, cover the development and testing of components of engines and of drive trains. The 6.2 propulsion activities are conducted by the Applied Technology Laboratory and the Propulsion Laboratory.

Combustors and Fuels – The objective of the Combustor Design Criteria Validation program initiated in FY76 was to refine existing combustor analytical design techniques to significantly reduce the design and development time of small gas turbine combustors. Within the first year of this program the contractor, AiResearch Manufacturing Company of Arizona, found that the computerized design techniques were very effective in designing other company combustors. The ARPA NAVSEA Ceramic Engine Combustor, the NASA T-1 Emissions Reduction program, the T-76 Uprate Combustor, and the TFE-731 and TPE-331 Combustors have all benefited from extensive use of these math models. Under this program, two advanced cycle, reverse-flow annular combustors of approximately 3 pps were designed and rig tested during FY77, with excellent results.

Turbines – The turbine tip clearance measurement programs were completed in FY77. The operating tip clearance of the first stage turbine rotor of the PLT-34 (Lycoming STAGG) was measured and recorded, using a laser-optic probe, while the clearance of the T700 first stage turbine rotor was measured using a high-response touch probe. Sufficient data were generated under each effort to allow comparison with tip clearance calculations, using the contractor's clearance prediction technique. The program also showed that (for cantilevered shrouds) thermal distortion of the shroud (out-of-roundness) was as severe as the clearance changes due to differential growth of the blades and shrouds.

Engine Rotor Dynamics – A Squeeze Film Bearing Damper Analytical program has been developed by Pratt & Whitney's Government Products Division. As a result, the response of squeeze film damper configurations can now be accurately predicted and better control over engine rotor shaft vibrations can be obtained. Development of this analytical program has included the successful simulation of a blade loss at both subcritical and supercritical operating speeds to verify the response of the squeeze film damper under these conditions.

Transmission Noise and Dynamics – A NASTRAN analysis has been developed by Boeing-Vertol which predicts the response of gearbox housings to internal gear and shaft excitation. This analysis has led to design techniques which have, to date, resulted in a 7-10 db reduction in noise level on a CH-47C forward transmission, and demonstrated a potential for greater noise reduction in future transmissions/gearboxes through selective stiffening of the transmission housing.

Inlet Protection Devices – A separator scavenge system, designed and fabricated based on recently established design criteria and design guide technical information, has demonstrated its ability to operate under icing conditions and to scavenge a variety of foreign objects without damage to itself. This same scavenge system had previously demonstrated a factor of five improvements in life in an erosive sand and dust environment. Based on the success of this system, a system of similar design is being used on one of the 800 SHP Advanced Technology Demonstrator Engines.

Overrunning Clutch – The high speed (20,000 RPM) 1500 HP Overrunning (free-wheeling) Clutch program is nearing completion. The Design Guide and Final Report are ready for publication. This program was launched in 1974 to demonstrate that weight and, therefore, cost savings could be realized if free-wheeling clutches were designed to operate on the highest speed shafts of helicopter transmissions. This objective has been accomplished. It has been demonstrated that freewheeling clutches designed for high speed and power are feasible and will save weight. The weight and cost savings study part of this program indicates that, if the present location of the freewheeling clutch was changed to the 20,000 rpm input shaft, a substantial weight savings would be realized. In the case of the spring clutch, this

savings would amount to 36.6 pounds per aircraft and for a fleet of 1,106 aircraft this would be 40,480 pounds with a fleet effective cost savings of 4-5 million dollars. This cost savings is almost entirely due to aircraft life cycle cost savings resulting from reduced weight.

Advanced Coupling – In 1974, an Advanced Coupling Program was initiated with the objectives of demonstrating high speed, lightweight, large deflection coupling technology. The initial objectives were to demonstrate 20,000 rpm at 1500 hp. These objectives have not been met to date but significant progress has been made. The most recent coupling design (see figure 25) has been successfully operated at 16,000 rpm, 1200 hp and 1.5° continuous misalignment. This interim step was achieved through the application of advanced composite material which minimizes the previously encountered fretting and failure of the flexures. The coupling weight of approximately 3/4 pound is particularly impressive when considered in conjunction with the demonstrated speed, torque, and deflection capabilities. A significant interim step in high speed, lightweight coupling technology has been demonstrated under this program.

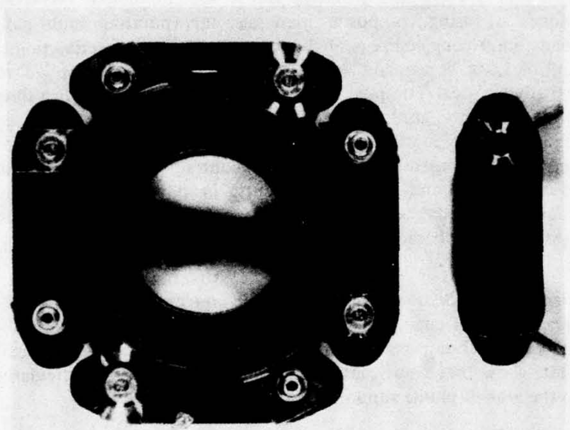


Figure 25. Advanced technology coupling with composite flexure straps.

Small Turbine Engine Research – Many areas of research can be more efficiently investigated in full scale engine investigations than in component rigs. Several such areas are planned using such engines as the T63, T702, and T700 as experimental vehicles for conducting research investigations. The first of these used the T63-A-700 to investigate the effect of IR (Infrared) suppressors on engine shaft power and fuel consumption. Results showed no measurable difference between standard exhaust stacks and the IR suppressors shown installed on the engine in figure 26. A technical publication reporting these results is in preparation.

Seals – Several programs are underway to improve technology for transmission seals, high speed engine seals, and abradable turbine seals. Notable progress has been made in spiral groove mainshaft seals. In the first known application of spiral groove geometry to self-acting seals, demonstration tests at sliding speeds of 800 fps (greater than required for small turbine engine application) were highly encouraging. This concept is being designed into the AVCO Lycoming version of the 800 HP ATDE.

RELIABILITY AND MAINTAINABILITY

The basic R&D effort in this area is to conduct those exploratory development programs necessary to develop advanced technology

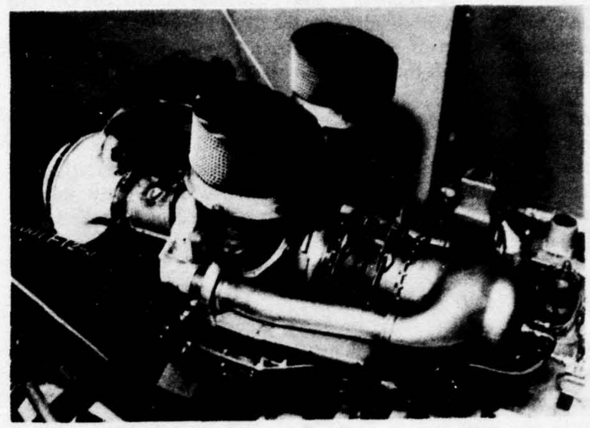


Figure 26. Infrared suppressors installed on T63-A-700 helicopter engine.

and equipment with improved military operational capability for Army aircraft through improved reliability and maintainability characteristics. The 6.2 R&M effort is conducted by the Applied Technology and Propulsion Laboratories.

Logic Model Test Set – The design of a Laboratory developed Logic Model (LOGMOD) test set has been completed. The LOGMOD concept functions as an engineering design evaluation tool and provides the basis for advanced trouble-shooting and diagnosis. A scale model helicopter demonstration unit has been fabricated and Army aircraft hardware, such as the ARC-51B helicopter radio set, have been modeled. Presently a joint Army and Air Force evaluation of the test set on the AN/APN-147 radar is underway. Other on-going evaluations of the LOGMOD concept include: the Naval Training Equipment Center; the Naval Underwater Systems Center; the Naval Electronics Command; and the Army Missile R&D Command. The LOGMOD fault isolation technique is illustrated in figure 27.

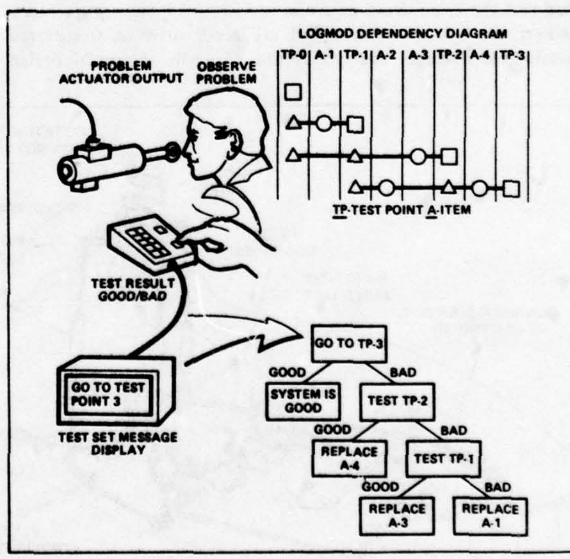


Figure 27. LOGMOD fault isolation technique.

ARMS Model Analysis – The Aircraft Reliability and Maintainability Simulation (ARMS) model was used to conduct sensitivity analysis on the SOTAS airborne radar surveillance system for the

UH-60A and UH-1H aircraft. Two additional aircraft, the OH-58B and AH-1S, have been added to the ARMS analysis. ARMS II, the advanced version of ARMS, has been completed for the AH-1G and CH-47 aircraft for future analytical efforts.

Oil Wetted Components Monitoring – Advanced chip detector and oil filtration investigations have documented that on-site diagnosis for oil wetted components can be performed. Modifications to incorporate advanced particle separation with full flow through burn-off chip detection utilizing disposable filters have been proposed for helicopter engines, transmissions, and gearboxes.

SAFETY AND SURVIVABILITY

Survivability means the ability of an aircraft to continue functioning after being hit by projectiles or fragments from air-to-air and ground-to-air guns and missiles. Flight safety concerns itself with the reduction of operational hazards. The basic thrust of these programs is to combine the best capabilities of government and industry to accomplish the design of aircraft with inherent survivability and flight safety. The program consists of research studies, materials development, engineering, testing, analysis, and systems safety and survivability design. These efforts are conducted by the Applied Technology Laboratory.

Ballistic Protection – The program to establish test data on the impact of 23 mm HEI-T projectiles on Army helicopter tail booms has been very helpful in selecting a practical design concept for reducing the ballistic vulnerability (23 and 30 mm) of UH-1H and AH-1G/S tail booms. Preliminary ballistic testing conducted by the Ballistic Research Laboratories indicated that the UH-1 helicopter tail booms and, to some extent the AH-1 tail booms, were vulnerable to the 23 mm HEI threat. Studies were initiated to define failure mechanisms and to develop a vulnerability reduction design. As a result of this effort, two designs were fabricated and tested which were applicable to both the UH-1 and AH-1 type helicopters. These techniques were effective in lessening major structural damage, but did not address the tail boom drive shaft or flight controls in the boom area. Additional ballistic testing was conducted on the AH-1S production-type tail boom which indicated that the basic structure could survive two hits, in some cases; however the control system and tail rotor drive shaft suffered considerable damage. The possibility of applying similar design techniques to the much smaller tail boom of the OH-58 was investigated. Preliminary tests indicate that the major damage causing mechanism on this boom is the overpressure caused by the functioning of the 23 mm HEI projectile. Blast overpressure caused some damage in the larger tail booms but is catastrophic in the smaller size.

Another area of ballistic protection R&D, is the joint USAF/Army test program for 23 mm HEI combustion threat potential and evaluation of "Explosafe" as an explosion suppressor. This test program is conducted at the Ballistic Test Range to determine the blast and ignition response of the 23 mm HEI projectile in dry bays and fuel tanks. Baseline data was obtained on the blast and combustion overpressure as a function of volume, combustible gas content, and level of inert gases of nitrogen and Halon 1301. The damage effect was assessed based on pressure alone without the compounding effects of fragments. The performance of "Explosafe" in reducing the terminal effects of the 23 mm HEI will be evaluated.

A study to compare the conventional AH-1 primary flight control system to a ballistic damage tolerant (BDT) system using a 12.7 mm API tumbled projectile threat was completed. The techniques of using composite materials, incorporating multi-path loads, improving component support, improving connecting points and bearing areas, and using tougher metals were applied to existing critical components to develop preliminary subsystem design layouts containing BDT components as illustrated in figure 28. The results of the design study indicated a significant reduction (compared to conventional contract) in vulnerability, in lower weight and cost components, in minimum installation changes, in equal or better reliability, in maintainability, and in system safety characteristics.

Signature Reduction – The air mixer concept for infrared (IR) suppression of engine exhaust has been tested. This concept integrates both hot parts and engine exhaust plume into one design. Tests show that significant results have been achieved, particularly in the area of plume suppression.

The analytical procedure for prediction of the radar cross section (RCS) of helicopters has been improved with additional capability to predict RCS of absorber type materials. RCS reduction

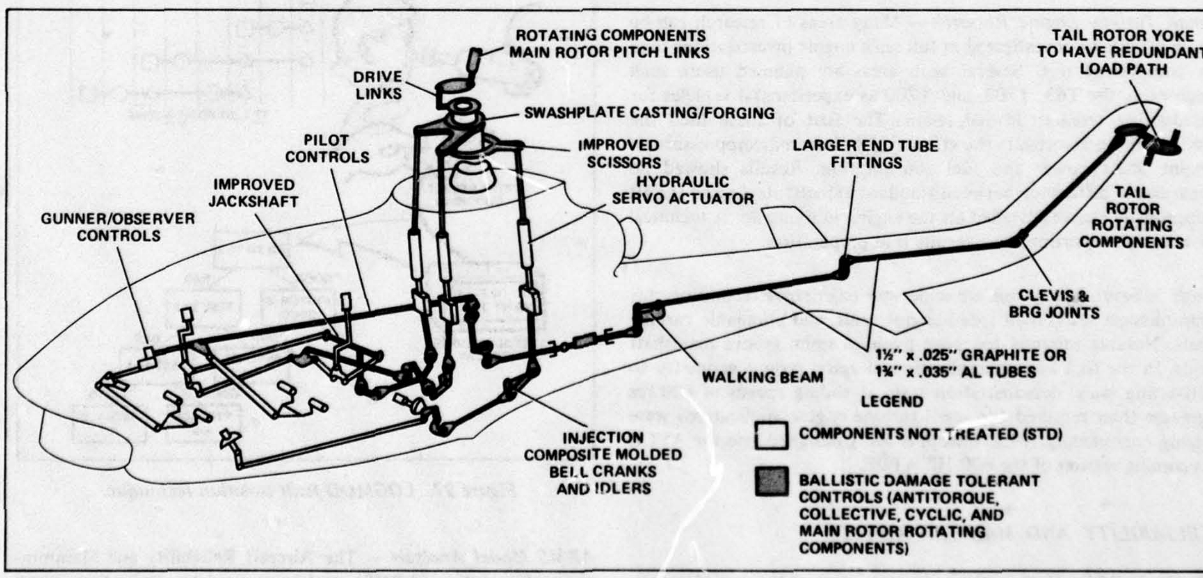


Figure 28. AH-1S preliminary design ballistic damage tolerant single primary flight controls.

evaluation has continued with measurement of shaped helicopter fuselages and field evaluation of low RCS main rotor blade hardware. The AH-1G main rotor hub cover has been fabricated, static tested for RCS levels, and is being qualified for limited flight evaluation.

Laser countermeasuring investigations have continued with completion of high energy laser protection concepts. These concepts include materials for reflecting and absorbing energy. Aerosols and dispenser systems concepts for use with helicopters to provide protection in the areas of laser and visual acquisition are being developed.

Flight Safety – The crashworthy pilot/copilot seat under consideration by the contractor for installation in production versions of the UH-60A (Black Hawk) helicopter was subjected to a series of vertical drop tests at the Naval Air Development Center facility in a joint Army/Navy/Industry program. The seat successfully met the dynamic (vertical) test criteria contained in TR 71-22 and MIL-S-58095. Subsequent testing will utilize 5th and 50th percentile anthropomorphic dummies to obtain data relative to energy absorber behavior throughout the size range of 5th to 95th percentile Army aviators.

Accident Information Retrieval System – Preliminary design and analysis of the Accident Information Retrieval System (AIRS) was accomplished. The AIRS is a low cost, low weight system that will record flight and crash impact data; and, if installed in Army helicopters, has the potential to reduce accidents and improve crash survivability by

- Rapid identification of crash causing system failures.
- Enhancing validity of accident investigations while reducing their time and cost.
- Timely identification of unsafe operations.
- Providing the basis for improved crashworthiness design criteria.

MISSION SUPPORT

Mission support technological development effort is directed toward the equipment which will enhance the effectiveness of military operational capabilities of Army aircraft, particularly in the forward areas. This effort is conducted by the Applied Technology Laboratory.

Cargo Handling – Army aviation mid-intensity warfare doctrine in the presence of an enemy with a high quality air defense threat will dictate that helicopters in use for supply/resupply missions must utilize terrain flying for survival. This doctrine represents a departure from present techniques and requires the exploration, assessment, and analysis of innovative approaches to enable the utility helicopter to perform its mission requirement.

The CH-47 and UTTAS performance characteristics have been analyzed with respect to this role and baseline performance and limits defined. The CH-47 contractor is working on a preliminary design of a device to "snug" loads up to the airframe; this would reduce overall height and prevent pilot-induced shifts and load oscillations with the least impact on maneuverability and performance. The UTTAS contractor is investigating the use of a two-hook kit which will also reduce and control oscillations and reduce the overall height. These improvements will also improve the night and instrument flight condition capabilities by improving handling qualities. The UTTAS concept is shown in figure 29 and the CH-47 load snubbing concept is shown in figure 30.

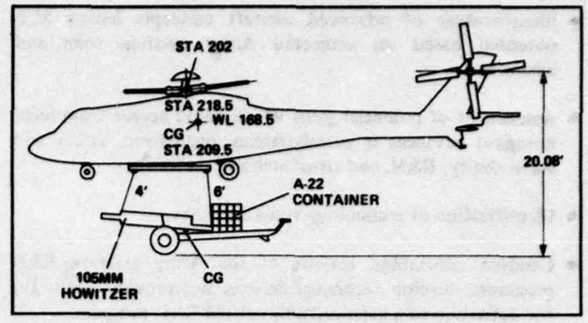


Figure 29. UTTAS tandem hook beam concept.

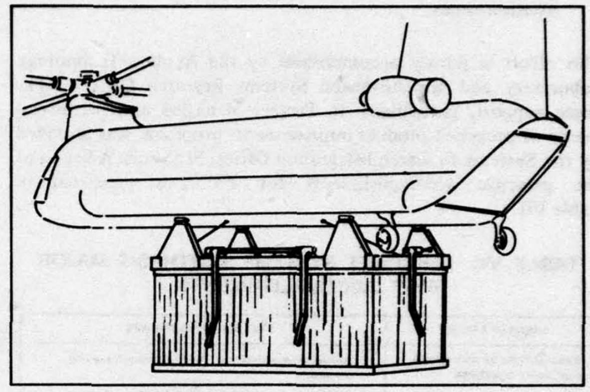


Figure 30. CH-47 load snubbing concept.

Helicopter Ground Mobility Systems – Concept formulation, selection, and definition analyses were completed on a common ground mobility system for the YAH-64 AAH and UH-60A Black Hawk helicopters. Additionally, a skid helicopter adapter was designed for use on all UH/AH-1, OH-58, and OH-6 series helicopters. The objective of this effort is a highly mobile air and ground device which will provide rough terrain ground mobility to tactical helicopters for combat area concealment and maintenance related movement purposes. Contracted fabrication of test models was initiated to provide hardware for concept and performance verification using applicable aircraft at Army test and operational sites.

Advanced Technology Ground Power Unit – Concept selection and definition work was completed for an aircraft ground power unit which will provide all necessary ground power for the YAH-64 AAH, UH-60A Black Hawk, and YCH-47 Modernized Chinook from one compact, lightweight, and highly mobile ground unit. The ground power unit will be air transportable and can be sling-carried for a UH-1, UH-60A, CH-47 or CH-54 helicopter. The unit will have rough-terrain, self-propelled ground mobility for movement around combat area maintenance sites. Procurement of test models for concept verification and performance assessment was initiated.

AIRCRAFT SYSTEMS SYNTHESIS

Aircraft systems synthesis has as its objectives the definition of a firm technology base that meets projected Army aviation requirements through exploration of new scientific knowledge. The overall approach involves:

- Ascertaining the needs and requirements of advanced airmobile systems.

- Identification of advanced aircraft concepts having high potential based on projected Army aviation roles and missions.

- Assessment of potential gains which could accrue from technological advances in aerodynamics, propulsion, safety and survivability, R&M, and structures and materials.

- Identification of technology voids and risks.

- Conduct continuing reviews of the Army aviation R&D programs, develop recommendations and provide inputs for the definition of a balanced and unified R&D program.

- Improve the in-house capability to assess the application of new technology and advanced airmobile concepts to Army aviation needs.

This effort is jointly accomplished by the Applied Technology Laboratory and the Advanced Systems Research Office, RTL. Some support, particularly to Project Managers and for assessments of proposed product improvements programs, was provided by the Systems Research Integration Office, St. Louis. A listing of the principle accomplishments for FY77 is presented in Table VII.

TABLE VII. AIRCRAFT SYSTEMS SYNTHESIS MAJOR FY77 ACCOMPLISHMENTS.

AREAS OF EFFORT	FY77 ACCOMPLISHMENTS
EVALUATION OF ADVANCED AIRCRAFT CONCEPTS	• Refined and expended in-house design and performance programs • Developed cost estimation methods for advanced engines and rotor blades • Hind D evaluation completed • Concluded participation in TRADOC HELCOM Study • DARCOM "SOTAS" preliminary design finished
ANALYSIS OF ARMY AVIATION R&D PROGRAMS	• Evaluated the effects of tip-speed on helicopter noise • Assessed effects of aerodynamic and structural improvements on rotor performance • Analyzed effects of propulsion technology advances (ATDE) • Conducted risk analysis for ATDE source selection • Conducted OH-58 mast mounted sight risk assessment
PROJECT MANAGER SUPPORT	• ASH – Design studies of new developments, off-the-shelf and interim ASH's Draft ROC review and design analysis • RPV – Developed computerized design and performance program Conducted design optimization study against a matrix of mission and performance requirements • SSEB design, performance and weights analyses support for Black Hawk and AAH
ORDERLY PLANNING AND PROGRAMMING OF ARMY AVIATION R&D	• Planned and conducted efforts to establish a joint NASA/Army man-machine integration research program • Participated in AVRADCOM/interagency efforts to identify avionics technology requirements and criteria for on-board equipment • Participated in investigation and demonstration of new technologies in advanced guns, fire control and special submunitions. • Completed 6th edition of Army Aviation RDT&E Plan • Published Laboratory SPF/SPEF Reports
FOCAL POINT FOR ARMY AIRMOBILE R&D	• Conducted interagency coordination, liaison, and problem identification efforts • Conducted interagency study with the Electronics Command on the development of a special display device • Evaluated industry and university R&D proposals

AIRCRAFT SUBSYSTEMS

This project provides visibility to the technological development efforts of aircraft subsystems that have been overshadowed in the past by subsystem R&M programs and/or off-the-shelf equipment. The objective of the project is to advance the state-of-the-art for Army aircraft subsystems such that significant improvements in operational effectiveness and/or reduction in life cycle costs can be achieved.

Nickel-Cadmium Battery – The Ni-Cad battery has a history of explosions, fires, and accidents in the fleet of Army aircraft. This battery is best suited to a constant current type of charge and the Army application has always used the battery directly on a constant voltage buss. Aging or unbalanced cells, excessive compartment temperatures, and poor maintenance can increase the probability of thermal runaway of the Ni-Cad with resulting battery destruction and possible in-flight fires. There are several well-documented aircraft losses caused by Ni-Cad battery failures.

A BIU (Battery Interface Unit) is presently being investigated which will have universal application to all aircraft with Ni-Cad batteries. Three flight configuration prototypes have been built and are being tested to verify the application and concepts. These units are capable of operation from either an ac or dc electrical system and are successful in preventing thermal runaway and reducing battery maintenance requirements.

Helicopter Ice Protection – R&D efforts to date have established meteorological ice protection design criteria for helicopters and have concluded that technology capable of providing satisfactory ice protection systems for current and future Army helicopters exists with the exception of rotor blade protection. Weight penalties attendant with rotor blade ice protection are significant for large helicopters and prohibitive for smaller helicopters such as the OH-58, AH-1G, and UH-1H.

In an effort to overcome this technology void, R&D efforts have been initiated to investigate the feasibility of microwave and vibratory rotor blade ice protection concepts. Both analytical and experimental investigations have been conducted into this study. The analytical work was conducted in an effort to establish the feasibility of this concept in its application to helicopter rotor blades. Recently completed laboratory experimental investigations have verified the microwave theory and its application to the ice removal problem. This work has shown the microwave ice protection concept to be viable for Army helicopters and one which warrants pursuit into the 6.3 area. The investigation into the vibratory ice protection concept was analytical in nature and investigated the feasibility of such an application as well as the potential areas of impact on the aircraft and its components. A number of schemes for introducing the vibratory motions into the rotor blades were investigated. It was concluded that the vibratory ice protection concept is feasible and should be pursued into the dynamic test phase.

RPV SUPPORTING TECHNOLOGY

The exploratory development RPV technology development activities are conducted by the Applied Technology Laboratory; the programs seek to eliminate the technological voids in air mobility which hamper the development of mini-RPV's (less than 200 pounds) for military applications. The key air mobility disciplines necessary to the development of mini-RPV's are: propulsion, launch and recovery, survivability/vulnerability, RPV configuration, structures, and flight control.

Propulsion – The 20 hp mini-RPV demonstrator engine program has as its objectives the demonstration of an engine technology base for future Army Mini-RPVs. It is to provide flight-weight engines in the 15-20 hp class which address current problems of high vibration levels, short life, high SFC and cost, and to provide the Army with a future source of supply for these engines. The approach to these objectives is to develop a twin-cylinder, two-stroke engine addressing known problem areas, while retaining maximum utilization of high production rate small engine components. The twin-cylinder approach reduces the vibration. The two-stroke approach reduces weight. The use of high production rate components reduces the overall cost.

Launch and Recovery – A survey study of recovery systems for Army use has been completed and, as a result, the testing of low altitude parachutes for tactical recovery and system safety backup is underway to obtain definitive data. Several other recovery system improvements are being monitored which could improve the present recovery systems size and mobility. Launch concepts and associated systems are also being investigated for possible application to future RPV systems. The study will evaluate launcher designs and provide a ranking for further selection, design and testing.

Survivability/Vulnerability – Test data on the radar cross section of the AQUILA RPV have been obtained, and three methods of treating the AQUILA to lower the RCS were investigated. The ability of various threat radars to track the AQUILA has been analyzed, and the data is being examined for impact on RPV survivability. Methods of reducing the propeller noise are being investigated to determine the optimum propeller configuration with respect to both performance and noise considerations.

RPV Configuration – The completed aircraft configuration studies have investigated a number of design matrix considerations. The studies have, in general, shown that RPV performance is relatively independent of the type of RPV (all wing, conventional or delta), but that the selection of the fixed pitch propeller is crucial to obtaining good performance in low speed climb and medium speed loiter.

Structures – The applicability of an advanced structure (Spacewind) was investigated in a contractual study and determined to be a promising, lightweight, low cost concept. The results of this study will be integrated with the results of an Air Force program to investigate low cost RPVs, and a final report covering all efforts will be written.

Flight Control – A family of electromechanical actuators suitable for mini and larger RPVs have been designed, fabricated, and will be ready for qualification testing early in FY78.

MAN-MACHINE INTEGRATION

Exploratory development in aviation human engineering methods and technology became a formal part of the RTL 6.2 program during FY77. The goal of this technical area is to provide advanced methods with proven effectiveness for use by AVRADCOM in performing the system integration functions during design, development and testing of Army air mobility systems.

Efforts in this discipline are aimed at improving design procedures, engineering methods, technical design data, system analysis and prediction procedures, and test or verification procedures for cockpit and other man-machine interface elements.

During FY77 staffing and joint planning was accomplished to initiate work at the Aeromechanics Laboratory. The NASA collocated facilities provide an excellent research environment for experimental studies emphasizing analytical, simulation, and behavioral testing of both hardware concepts and man-machine integration methodology. Significant support was provided to the flight simulator development task in the areas of visual and motion display requirements, computer generated imagery development and evaluation, and facility planning. Interagency research was jointly conducted with U.S. Army Human Engineering Laboratory (HEL) and with U.S. Army Avionics Laboratory. The HEL project is focused on mathematical modeling for computer aided task analysis. Joint development of a kinesthetic-tactual display concept with Avionics Laboratory resulted in a demonstration in which Army pilots flew, hovered, and manuevered a simulated helicopter by means of information transmitted solely by the touch sense modality as illustrated in figure 31.

Figure 31. Single-channel kinesthetic-tactual display adapted to helicopter collective control grip (concept has been applied to a 2-channel cyclic control grip).

AIRCRAFT WEAPON TECHNOLOGY

The Army aircraft weaponization program provides the capability of delivering ordnance to destroy, neutralize, or suppress those targets jeopardizing ground or airborne forces in the conduct of the land combat role. This capability depends on the adequacy and timeliness of the aircraft weapons technology. Within the AVRADCOM mission requirement to develop aviation systems, including the interface of aircraft subsystems and aerial armament subsystems, RTL have the responsibility to advance the technological base for aircraft weaponization applications. Primary performing Army activities for R&D of aerial armament systems include the ARRADCOM, MIRADCOM, and AVRADCOM.

Separate Loaded Ammunition – The Separate Loaded Ammunition (SLAMMO) concept consists of a thick aluminum, reverse tapered, case which contains the propellant and is enclosed with an environmental seal. The projectile is separate from the case gaining an additional advantage of being able to employ different types of projectiles, such as armor piercing and high explosive. The SLAMMO case is 50% lighter than that for a comparative conventional case and 30% lighter than a comparative telescoped case. In addition, the total concept, when assembled for firing in the weapon, requires 50% less space than a conventional round, and slightly less than that for a telescoped round. SLAMMO also offers an additional benefit in ballistics since action time is minimized and a two-step ignition systems is not required as is for the telescoped concept. From a standpoint of cannon mechanism design, reduction in case length allows reduction in cyclic stroke which provides for smaller and lighter total gun systems configurations. Work to fabricate a SLAMMO firing fixture was performed during FY77.

HIGAD Demonstration – The High Impulse Gun Airborne Demonstration (HIGAD) is an exploratory development that involves the integration of several programs to demonstrate that a powerful automatic cannon (150 lb-sec impulse) can deliver precision fire at a range of 3,000 meters or greater. There are several expected benefits from the effort including definition of integration problems, identification of error sources, and the demonstration of potential development areas where advanced development should concentrate. The effort will be directed to adapting existing hardware assets for the system demonstration in FY79. The AMCAWS 30 automatic cannon that fires telescoped 30 mm ammunition will be installed in a hydraulic constant recoil control unit and tested to confirm that its 150 lb-sec impulse can be averaged over the entire firing cycle. If this test is successful, the gun and recoil unit will be installed in a limited flexibility gimbal for mounting on the multiweapon fire control COBRA helicopter (see figure 32).

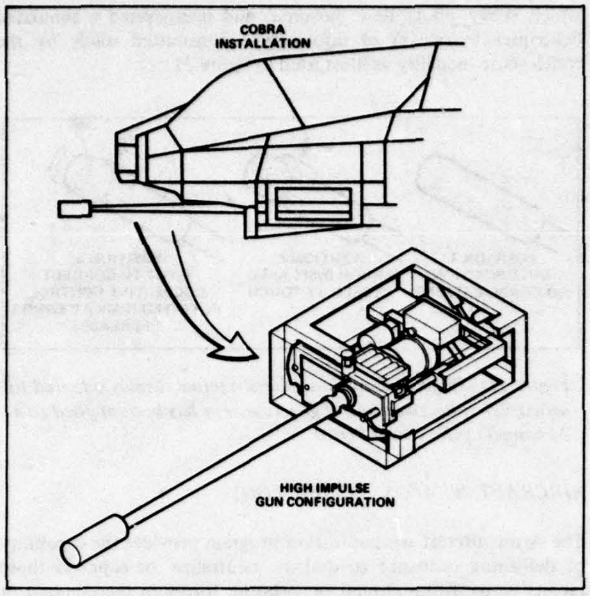


Figure 32. HIGAD system test bed.

Millimeter Wave Radar – A radar design effort has been performed to address the development of signal processing techniques which will allow the AN/APQ-137 radar to be used in the air-to-ground role for fire control purposes. Also, the ability to address air-to-air targets has been considered. This development is intended to provide a long-range target acquisition capability.

ADVANCED TECHNOLOGY DEMONSTRATION – PROGRAM CATEGORY 6.3

TILT-ROTOR RESEARCH AIRCRAFT

The Tilt-Rotor Research Aircraft is a joint Army-NASA program to demonstrate, in flight, the attainment of the technology required to implement the tilt-rotor concept. The concept unites the speed and economy of fixed-wing turboprop aircraft with the VTOL capability of the helicopter.

The first of the two aircraft to be built for the program was rolled out at the contractor's Flight Test Facilities in Arlington, Texas, on 22 October 1976. Among the attendees at the rollout were MG J. Lauer, HQ DA; Mr. R. E. Smylie, NASA HQ; and Congressmen J.Wright, D. Milford, and O. Teague of Texas.

After several months of integrated systems tests and ground tie-down tests, Aircraft No. 1 made its first hover test flight on 3 May 1977. A total of three flight hours were completed with that aircraft during May. The tilt rotor (XV-15) aircraft is shown in figure 33. Speed ranges covered, all below an altitude of 100 feet, were up to 40 knots in forward flight, 15 knots lateral, and 10 knots rearward. The aircraft's flight handling qualities were judged satisfactory within the speeds covered.

Aircraft No. 1 will be tested in the Ames 40- by 80-Foot Wind Tunnel during FY78 following completion of its scheduled ground tiedown testing and teardown inspections. Construction of Aircraft No. 2 is near completion.

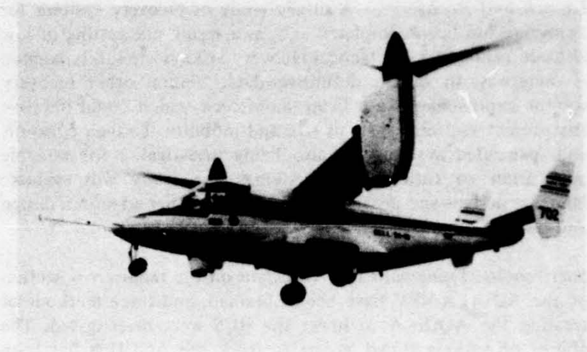


Figure 33. XV-15 Aircraft No. 1.

ROTOR SYSTEMS RESEARCH AIRCRAFT

The Rotor Systems Research Aircraft (RSRA) program, a joint Army/NASA effort, will provide flight research capability to

- Evaluate promising new rotor concepts,
- Verify numerous supporting research technologies, and
- Test product improvement rotors.

Under contract, Sikorsky Aircraft has completed fabrication of both RSRA. Figure 34 shows the first aircraft in the helicopter configuration in flight. Figure 35 shows the RSRA in the compound configuration during recent ground tests. First flight of the RSRA occurred on 12 October 1976 at the contractor's facility. Helicopter and helicopter with compound lower horizontal tail flights have been completed for a total of 32 flights and 23.1 flight

Figure 34. RSRA in helicopter configuration in flight.

Figure 35. RSRA in compound configuration.

test hours. In preparation for engineering development flight tests in the compound configuration, RSRA Number 1 was ferried to Wallops Flight Center on 21 July. Full-up compound flight tests are scheduled to start by mid November. Aircraft shake tests have been completed on Aircraft Number 2 with the Active Isolator/Balance System installed. First flight on Aircraft Number 2 with Active Isolator installed is expected to occur the last week in October 1977. Upon completion of a contractor demonstration program, the RSRA will be accepted by the government for an extensive rotor research program.

ADVANCED ROTOR TECHNOLOGY

Bearingless Main Rotor Concept – In an effort to reduce helicopter rotor complexity and costs, a program was initiated in June 1976 with Boeing-Vertol to evaluate a Bearingless Main Rotor (BMR) concept. This concept eliminates both the bearings and hinges in the main rotor blade retention system (pitch bearings, flapping and lead/lag hinges) by using a composite hub assembly flexible enough to accommodate normal blade pitch and flapping motions. Also included in this program is the updating of analyses for accurately predicting the dynamics and structural performance for this new concept where high structural flexibility is a necessary characteristic. Wind tunnel tests have been conducted on a Froude-scale model (1/5.8-scale) of the BMR/BO-105 helicopter. Correlation of wind tunnel results with analysis was good. Nonrotating natural frequency bench tests have been performed, with results similar to the predicted values. Static strain survey and deflection tests have been conducted. The test specimen flap, chord and torsional stiffnesses indicate the beam assembly structural properties are compatible with the desired stiffness distributions. The beams showed no signs of failure when subjected to loads in excess of the limit load condition.

Final evaluation of the BMR concept will come from flight-test results of the BMR on a BO-105 helicopter in July 1978. Successful completion of the program will enable the U.S. Army to develop rotor systems that offer substantial improvements in maintainability and reliability while reducing cost, weight and complexity.

Advancing Blade Concept – The Advancing Blade Concept (ABC) is a coaxial, counterrotating, hingeless rotor system. The main advantages of this rotor are: alleviation of retreating blade stall, which provides improved maneuverability at high advance ratios and altitudes; and deletion of the tail rotor with attendant benefits in safety, compactness, vulnerability, noise, handling qualities, and hover performance. The program is under contract to Sikorsky Aircraft.

On 9 March 1977, the basic helicopter flight-test program was completed. The aircraft had been flown 67 hours at speeds up to 196 KTAS and load factors to 2.55 g. Flight testing confirmed advantages of this concept and identified some shortcomings. Blade stall boundaries were encountered only at high advance ratios and high altitudes. The aircraft demonstrated rapid control response about all three axes with a minimum of cross-coupling. The benefit of not having to power a tail rotor was verified during hover performance. A low noise signature, attributed to a relatively low blade tip speed and lack of a tail rotor was noted. Structural loads in the rotor and control systems ranged from low to moderate indicating potential for substantial weight reduction. Weak directional control power in partial power descents and autorotation was observed.

Under a joint Army/Navy/NASA program, the aircraft is being equipped with two 3,000 pound thrust turbojet engines for high speed flight testing. In addition to the flight tests, further testing in the Ames 40- by 80-Foot Wind Tunnel will provide data relative to rotor drag reduction, tail/rotor aerodynamic interference, and different control configurations. A 1/5 scale wind tunnel model of the ABC in the compound configuration is shown in figure 36.

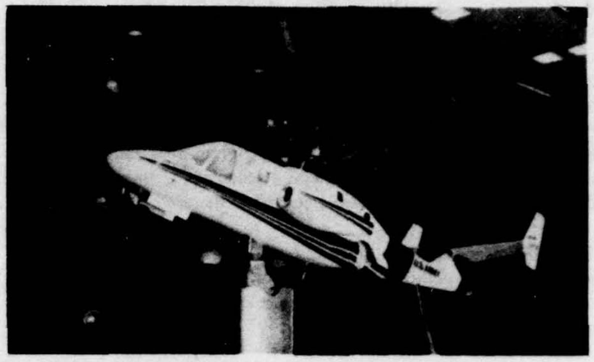


Figure 36. 1/5 scale model of the ABC compound configuration.

Second Generation Comprehensive Helicopter Analysis System – The objective of this R&D task is the development and demonstration of an analytical model to accurately predict the aeroelastic stability, stability and control, performance, loads and acoustics characteristics of rotary wing aircraft, figure 37. Once developed, the system will reduce engineering development cost and risk for new helicopters, prevent delay in deployment of new aircraft, provide the Army with a reliable evaluation tool, reduce reliability, maintainability and safety problems of operational aircraft, and solve technical problems restricting operational capabilities. The specific needs for the system have been defined and the development approach has been established. A Government/Industry working group has participated in the planning in an advisory capacity. An initial development plan and initial Type A System specification has been written. A three-contract predesign effort will improve the initial Type A System specification, define the feasible system capabilities, design the System, produce an associated set of Type B5 development specifications, and produce a baseline development plan.

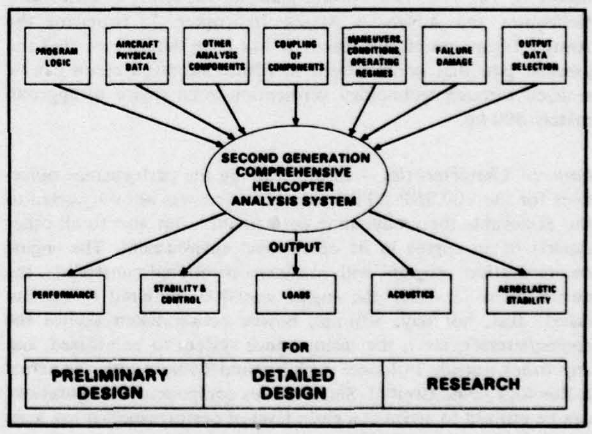


Figure 37. Second generation Comprehensive Helicopter Analysis System.

ADVANCED AIRCRAFT STRUCTURES

Structural Integrity Recording System – Fatigue lives of AH-1G dynamic components are presently calculated based on the fatigue strength as determined from component tests; the loads and stresses occurring in flight as determined by a strain survey; and an

estimated percent of time that the helicopter will be operated in each of the flight conditions investigated during the flight strain survey.

The Structural Integrity Recording System (SIRS) is being developed to accurately measure the time spent in each flight condition. This subsequently permits a separate fatigue damage calculation to be made for each aircraft based on actual usage. The SIRS consists of an airborne recorder and transducer installation kit; a data retrieval unit; and a fatigue damage assessment system (FDAS) software package for calculating fatigue damage. The data is processed by the FDAS software program at a data processing center and reports generated which calculate cumulative fatigue damage for the critical dynamic components.

The SIRS has successfully completed an environmental test program which included dust, vibration, temperature-altitude, temperature-altitude-humidity, acceleration, explosive atmosphere, humidity, and EMI testing.

Flight test of the prototype SIRS was conducted on an AH-1G at Ft. Rucker, Alabama, in May 1977. The data from onboard oscillograph records were processed manually to determine time in each flight condition and compared against the time recorded by the SIRS. Good correlation existed for essentially every flight condition. During the fourth quarter FY77, SIRS was installed on five AH-1G aircraft at the U.S. Army Aviation School, Ft. Rucker, Alabama, in preparation for the five-month operational evaluation of the SIRS.

800 SHP ADVANCED TECHNOLOGY DEMONSTRATOR ENGINE

Basic and exploratory development programs have provided a firm basis for the advanced development demonstrator gas generator/engine programs. Two successful programs that have used this "building block" philosophy are the 1500 HP Demonstrator Engine program and the Small Turbine Advanced Gas Generator (STAGG) program. The 1500 HP Demonstrator Engine program identified the capabilities and limitations of an advanced engine in that size class. An engineering development program (T700) followed. The T700 is the power plant for the Army's Black Hawk Helicopter and Advanced Attack Helicopter. In reviewing the Army's future propulsion needs it has been determined that the greatest potential improvement in future aircraft systems can be realized through technology verification in an engine of approximately 800 hp.

Concept Characteristics – In determining the performance objectives for the 800 SHP ATDE, consideration was not only given to the achievable thermodynamic performance, but also to all other aspects of an engine in its operational environment. The engine demonstration program will consider operational constraints, the environment in which the engine would be required to operate (sand, dust, hot day, altitude, hostile action taken against the engine/aircraft, etc.), the maintenance system to be utilized, and any other outside influence which could compromise the actual technology demonstrated. Since various component configurations can be utilized to arrive at a given level of performance, it has been decided that two separate approaches should be taken in the ATDE program. Design and configuration data for the 800 SHP ATDE's is shown in Table VIII.

Objectives – Specific goals of the ATDE program are to

- Demonstrate improvements in specific fuel consumption of 17-20% and in specific horsepower of 25-35% as compared to current turboshaft engines in this power class.
- Demonstrate improved reliability, maintainability, and survivability characteristics.
- Quantify engine cost factors and identify areas where future development cost and acquisition cost savings can be made without compromising the engine's capability.

TABLE VIII. 800 SHP ATDE DESIGN AND CONFIGURATION DATA.

CHARACTERISTIC	DESIGN PARAMETER		REMARKS
	GMA 500	PLT 34A	
HORSEPOWER	• 600 hp	• 600 hp	• 4,000 ft 95°F Condition
	• 825 hp	• 825 hp	• Sea Level Std Condition
SPECIFIC FUEL CONSUMPTION (SFC)	• 0.550 lbs/hp-hr	• 0.550 lbs/hp-hr	• Maximum at Cruise
WEIGHT	• 220 lb	• 220 lb	• Maximum
OUTPUT SPEED	• 30,000 rpm	• 30,000 rpm	• Variable + 5% - 15%
INTEGRAL LUBE SYSTEM	• Yes	• Yes	
INTEGRAL INLET PARTICLE SEPARATOR	• Yes	• Yes	
COMPONENTS:			
COMPRESSOR STAGES	• 2 Centrifugal	• 2 Axial, 1 Centrifugal	
H.P. TURBINE STAGES	• 2 Axial	• 2 Axial	• Cooled
L.P. TURBINE	• 2 Axial	• 1 Axial	• Uncooled
FUEL CONTROL	• Electronic	• Electronic	• Full Authority with Manual Reversion
DESIGN LIFE	• 5,000 hrs	• 5,000 hrs	
MODULES	• 7	• 4	• Modular Maintenance

CARGO HANDLING EQUIPMENT

Cargo Acquisition – The technical feasibility of a helicopter transported Container Lift Adapter (CLAH) for acquiring, transporting, and delivering standard 8x20-foot MILVAN containers without the aid of ground handling personnel or prerigging has been demonstrated. A complete, detailed design for a lightweight, flightworthy, functional militarized version complete with interfacing components and subsystems has been completed. The all-electric CLAH is powered from the aircraft and controlled by the flight crew. A follow-on program calls for fabrication and flight test evaluation for operational variation.

Gondola Systems – Two gondola systems for the external transport by helicopter of noncontainerized cargo (vehicles, weapons systems, equipment, breakbulk) were fabricated and contractor static/ground tests completed (figure 38). Force Development

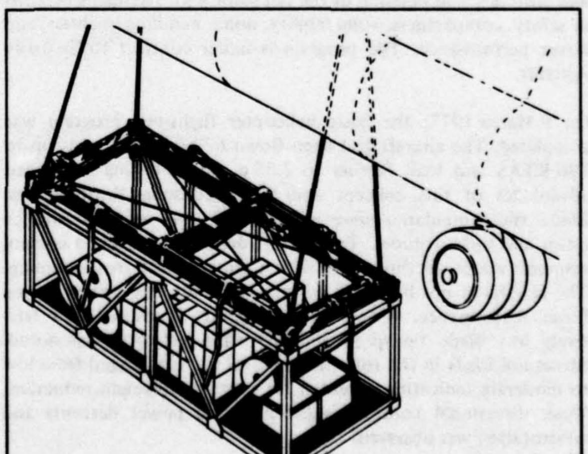


Figure 38. Gondola system for external transport of bulk equipment.

Testing and Evaluation (FDTE) for operational suitability was initiated, and various cargo loads and configurations, methods of loading/unloading, and compatibility with material handling equipment and cargo helicopters were demonstrated. Operational flight tests with dual hook CH-47 helicopter and evaluation of the gondolas in various FAARP configurations, with ordnance, vehicles, and other types of cargo is nearing completion. The results of FDTE will be utilized in a design analysis and assessment of advanced technology, lightweight, mission-configured gondolas followed by detailed design, fabrication and acceptance testing.

REMOTELY PILOTED VEHICLES

AQUILA – The AQUILA Remotely Piloted Vehicle (RPV) Program is being funded through the RPV Development Management Office of AVRADCOM and contracted with the Lockheed Missiles and Space Company through RTL. This RPV system will enable the TRADOC to evaluate the capabilities of mini-RPVs through "hands on" testing so that an ROC can be established if warranted. This is the first Army program utilizing a Letter of Agreement (LOA) management structure between the developer and user commands. Figure 39 depicts an AQUILA RPV (XMQM-105) system.

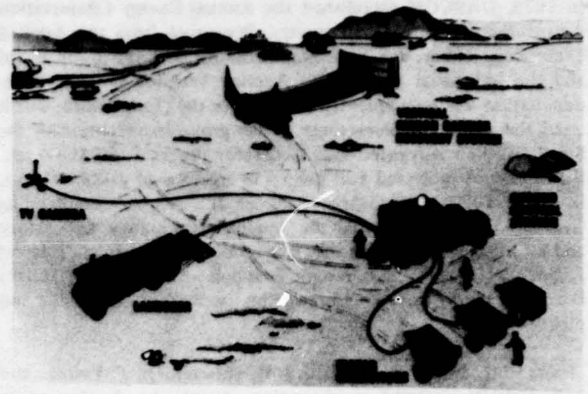


Figure 39. AQUILA RPV (XMQM–105) system.

HELICOPTER ICE PROTECTION

A helicopter ice protection program was initiated in July 1973 for the development of advanced anti/deicing systems for Army helicopters, present and future. This R&D effort has resulted in the establishment of meteorological design criteria applicable to both military and commercial helicopters and the determination that rotor blade ice protection for Army helicopters can only be met with advanced technology concepts. An advanced cyclic, electrothermal concept was designed and installed on a UH-1H test helicopter for engineering icing flight test purposes. The test helicopter has been subjected to simulated icing tests, using the U.S. Army Aviation Engineering Flight Activity helicopter icing simulation system, the Ottawa (Canada) Spray Rig, and natural icing condition tests at Ottawa. The testing was conducted to optimize rotor deicing system control parameters and demonstrate proper icing shedding characteristics. To date, a total of 63.3 productive flight-test hours have been accumulated in the simulated and natural environments. A total of 5.3 hours have been accumulated "in-cloud" in natural icing testing. Tests have included the full spectrum of icing severity including a temperature range of 0°C to -20°C and liquid water content of 0.1 g/m^3 to 0.8/gm^3. During these tests, preliminary evaluation of the engine IR suppressor and the M-200 (2.75 mm) rocket system were conducted. Coordination with the organizations responsible for those subsystems has been continued, as well as with U.S. Army Training and Doctrine Command (TRADOC). Federal Aviation Administration, and U.S. Air Force Air Weather Service. An updated Joint DARCOM/TRADOC position on helicopter ice protection requirements is being prepared. Plans are underway for continued artificial and natural flight testing at Ottawa during the 1977-78 winter test season.

ACTIVITY INDICATORS

PUBLICATIONS

During FY77, the Army Research and Technology Laboratories originated a total of 248 reports, papers, and presentations. The total number of reports was 127 of which 67 were prepared (entirely or in part) by RTL employees and 60 were published under contracts. A complete listing of these publications and presentations is contained in Appendix B.

HONORS AND AWARDS

Mr. John A. Chappell, Jr., an electronics engineer with the Applied Technology Laboratory, Ft. Eustis, Virginia, received a plaque signed by The President of the United States in recognition of his selection as one of the Ten Outstanding Federal Handicapped Employees of 1977. The presentation was made by Mrs. Rosalynn Carter, the First Lady, and the Honorable Ersa H. Poston, Commissioner of the U.S. Civil Service Commission. Mr. Chappell has been paralyzed in both legs from the hips down since the age of nine because of a reaction to a rabies inoculation. In addition, Mr. Chappell was named the Army's No. 1 handicapped employee by Secretary of the Army Clifford L. Alexander, who also presented Chappell with the Army's Meritorious Civilian Service Award. And finally, the 34-year-old Chappell received the DARCOM handicapped award of the year from Major General H. B. Gibson, Jr., representing the Army Material Development and Readiness Command. The Federal Civil Service recognition for "exceptional job performance" is given annually to ten of the Nation's outstanding handicapped Federal employees. By highlighting the valuable contributions they have made, the government focuses public attention on the importance of using all of our human resources effectively.

Messrs. Timothy D. Evans, Robert A. Hall, and Gary Newport, assigned to the Reliability & Maintainability Technical Area of Applied Technology Laboratory, were selected as recipients of the Annual Army Research and Development Achievement award for 1977. The individuals were nominated for their outstanding team efforts in developing and applying a new analysis methodology that uniquely highlights the operational capabilities and deficiencies of candidate helicopters under consideration for procurement to fill the Army's requirement for a utility helicopter of the 1980-1990 time frame. This improvement in the capability to select the most cost and operationally effective candidate results from the precision of the data developed in a simulated evaluation of companies of aircraft performing typical Army mission in combat scenarios.

In 1976, DARCOM established the Annual Energy Conservation Award for individuals and groups. Personnel from the Applied Technology Laboratory were nominated for both the group award and the individual award. The Applied Technology Laboratory nomination was subsequently selected for the group award, which cited the specific achievements of the group in execution of the Small Turbine Advanced Gas Generator Program (STAGG) and the attendant projected fuel savings of millions of gallons of fuel. In April 1977, LTG George Sammet, Jr., Acting Commanding General, DARCOM, visited the Applied Technology Laboratory and awarded Messrs. Jan Lane, Kent Smith, Allen Royal, Edward Johnson, Albert Easterling, Graydon Elliott, LTC Millard Pedersen, and Robert Langworthy individual citations and plaques.

Messrs. I. E. Figge, B. L. Karp, J. W. Sobczak, E. T. Young, and L. D. Bartlett received a suggestion award for developing an improved rotor blade repair method.

Mr. C. H. Carper received Suggestion Award No. 52-7T, in April 1977, on the subject of "Reduced Requirements for Employee Performance Evaluations."

PATENTS

Mr. P. J. Haselbauer, Applied Technology Laboratory, received patent number 4,020,205 for his development of a continuous ribbon method of fabricating tetra-core. A $100 suggestion award was also received by Mr. Haselbauer.

OTHER ACTIVITIES

The American Helicopter Society national and regional officers include the following RTL personnel:

Andrew W. Kerr – Director at Large

Frederick H. Immen – Western Region Director

RTL is well represented on governmental and nongovernmental, technical and scientific committees of both national and international stature. The following is a listing of the organizations in which employees of the Laboratory participate as officers and/or members (a complete listing of committees, affiliation, and individuals is presented in Appendix C):

- American Helicopter Society
- American Institute of Aeronautics and Astronautics
- American Mathematical Society
- American Society of Mechanical Engineers
- Defense Atomic Support Agency
- Department of Defense
- Department of the Air Force
- Department of the Army
- Institute of Electrical and Electronic Engineers
- National Academy of Sciences
- National Aeronautics and Space Administration
- National Research Council
- North Atlantic Treaty Organization
- Society of Aeronautical Weight Engineers
- Society of Automotive Engineers
- Subsonic Aerodynamic Testing Association
- U.S. Civil Service Commission

SPECIAL ITEM

AVRADCOM ESTABLISHED

On July 1, 1977 AVSCOM was reorganized and merged with TROSCOM as two new commands were established in St. Louis. The new organizations are now known as the Aviation Research and Development Command (AVRADCOM) under the command of Major General Story C. Stevens, and the Troop Support and Aviation Materiel Readiness Command (TSARCOM), under the command of Major General Thompson. AVRADCOM is comprised of the research and development elements of AVSCOM, plus the Avionics Laboratory of the U.S. Army Electronics Command, Fort Monmouth, N.J. which will remain in place. TSARCOM was formed by merging the logistical readiness elements of AVSCOM with TROSCOM. TROSCOM is now located at the Federal Center on Goodfellow Boulevard, St. Louis, MO, and AVRADCOM is expected to move from the Mart Building to the Goodfellow address as soon as building renovations are completed. Major General Story C. Stevens and Dr. Richard M. Carlson, Director of this Laboratory, discuss the reorganization and the name change in front of RTL Headquarters (figure 40).

Figure 40. Major General Story C. Stevens and Dr. Richard M. Carlson in front of RTL Headquarters.

APPLIED TECHNOLOGY LABORATORY DIRECTOR

Colonel Emmett F. Knight was named Director of the Applied Technology Laboratory, Ft. Eustis, Virginia, formerly known as the Eustis Directorate. Colonel Knight succeeds Colonel George W. Shallcross who was appointed Project Manager of the Advanced Scout Helicopter Program. Colonel Knight is a Master Army Aviator and is a rated pilot in both fixed wing aircraft and helicopters. He was named Aviator of the Year in 1963 by the Army Aviation Association of America.

The facility complex available to the Army Research and Technology Laboratories is unique within the Government. It represents a special blending of both Army and NASA facilities which can be utilized to meet the R&D needs of the Army as well as the overall aviation community. The major facilities that are available to the Laboratory are indicated in Table IX.

TABLE IX. MAJOR FACILITIES AVAILABLE FOR R&D

• Acoustical test facility	• ILLIAC IV
• Cargo handling system integrated test rig	• Lunar lander facility
• Combustion research facility	• Materials laboratory
• Engine research facility	• Structures research lab
• Environmental test facility	• Structures testing lab
• Flight research facilities	• Vulnerability testing laboratory
• Ground based simulation facilities	• Whirl tower facility
• Heat transfer facility	• Wind tunnels

Facilities that have become available or are being expanded to assist the R&D engineer in the advancement of the technology base are briefly described below.

WALLOPS FLIGHT CENTER

The Wallops Flight Center and its attendant test ranges (figure 41) uniquely enhance the flight research effort of the Langley Research Center. Because it is NASA-owned and controlled, it can provide unencumbered access, and provide facilities for obtaining tracking information and aircraft noise characteristics in all modes of flight. These capabilities are an integral part of research programs dealing with rotorcraft external noise and acoustic footprint definition. The Aeronautical Research Radar Complex, Wallops Flight Center, provides aircraft position measurements with a one-foot precision using the FPS-16/Laser Tracking System. The tracking system provides omnidirectional coverage, permitting the investigation of complex trajectories and selection of any desired wind direction relative to the final approach heading. A two-way data link that operates between radar pulses is used to transmit aircraft state and other information to the Flight Display Research System. The remotely operated acoustic range at the Wallops Flight Center is capable of providing directly the ground noise footprints from helicopters inflight for a range of operating conditions. All of these facilities will be available and used in the flight operations of the Rotor Systems Research Aircraft.

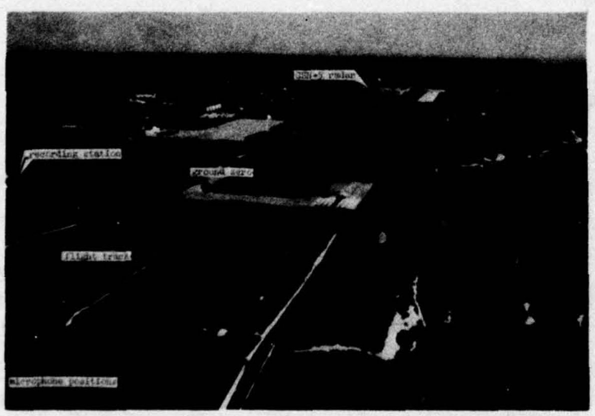


Figure 41. Instrumented flight range at Wallops Flight Center.

SMALL TURBINE ENGINE TEST CELL

The Propulsion Laboratory has activated a test cell at the NASA-Lewis Research Center, for conducting research programs using helicopter engines as the test vehicle. The test cell itself is capable of handling engines up to the size of the T55 although the power absorption system would require modification before engines larger than the T63 and T702 could be operated. Check out of the facility was carried out by performing tests on the T63-A-700 engine investigating the effect of OH-58 IR suppressors for the ASE PM. The next planned investigation is a joint NASA-Army program to evaluate an eddy current turbine crack detector concept in an operating engine.

The test cell is equipped with instrumentation for monitoring engine operating variables and controlling load by means of a water brake. Data is acquired on the NASA-Lewis CADDE system, an on-line digital data acquisition system which is tied in with the central system computer. Turn around time for reduced data at the test cell terminal depends on user load during tests but is normally less than three minutes.

NONDESTRUCTIVE TEST/INSPECTION FACILITY

The Applied Technology Laboratory is developing a comprehensive nondestructive test (NDT)/nondestructive inspection (NDI) capability responsive to Army aviation needs. With the increasing introduction of advanced composite materials, super-alloy metals, and advanced design concepts in Army aircraft, the need exists for the development of advanced NDT/NDI techniques and procedures for use during the research and development, manufacturing and fleet operation phases of the new airmobile system. The NDT/NDI techniques with the greatest potential application to Army aircraft structures and components have been selected by an AVRADCOM committee and, where possible, off-the-shelf equipment for each technique is being procured. A listing of the NDT/NDI capability being established at the Applied Technology Laboratory includes

- Portable X-Ray,
- Ultrasonic,
- Eddy Current,
- Image Enhancement,
- Boroscope,
- Remotely Articulated Fiberscope,
- Dye Penetrant,
- Neutron Radiography, and
- Infrared Radiography.

During FY77, the capability for performing x-radiography, acoustical holography, and image enhancement were added to the Laboratory. Familiarity with the new equipment and associated operating techniques in addition to the existing ultrasonics and eddy current techniques is being developed, and preliminary assessments of the inspectability limits of the advanced composite materials/components are being made. In addition, a neutron radiography system will be installed in the laboratory during early FY78. Acceptance testing of the n-ray equipment was completed late in FY77.

ANECHOIC ROTOR TEST SYSTEM

The Aerodynamic/Acoustic Rotor Test Chamber at the Aeromechanics Laboratory consists of an 800 sq ft test chamber and a two-story control room providing an additional 800 sq ft of space.

The test chamber is 26- by 32- by 28-in high and is acoustically treated with foam wedges. The air inlet area at the top of the test chamber is acoustically treated to attenuate external noise and isolate inlet flow from external winds. The test chamber has a vertically movable work platform/rotor wake ejector system and an acoustic wedge platform.

Test rotors operate in the center of the chamber with air drawn in through the acoustic inlet and the wake captured by the movable platform ejector system and ducted out of the chamber. Rotor aerodynamic performance and acoustic signature can be measured on hovering rotors up to 8 ft in diameter.

DATA TRANSLATION SYSTEMS

The objective of the Data Translation Systems is to provide the Applied Technology Laboratory with the capability to translate and process analog and serial digital data from a broad range of tape formats and tape speeds to a wide variety of output media. The signals can be recorded on one of the more conventional analog output devices (oscilloscope, oscillograph, or X-Y plotter) or processed by one of three digital systems. Data may be routed through an analog process such as filtering or envelope detection before entering one of the output translation systems. Data signals can be captured in either the time domain (4 channel waveform recorder of 8 channel analog-to-digital-converter) or in the frequency domain (real-time spectrum analyzer). Captured data, now in digital form, can be transferred into one of the data processors (HP 2100 computer or TEK4051 graphic calculator) for translation into engineering units and/or formatting for the required output device. The interactive processors provide the capability of listing, graphing, editing, storing, analyzing, comparing, formatting, and finally outputting the information. The output may be in form of a plot, printout in digital magnetic tape, or IBM compatible for further processing by IBM 360 via the Laboratory's COPE terminal.

APPENDIX A
RTL FY77 TECHNICAL PROGRAM STRUCTURE

CATEGORY	6.1 RESEARCH Project - Tech Area Title Funds: Amount*-%** of 6.1 for FY77	6.2 EXPLORATORY DEVELOPMENT Project - Tech Area Title Funds: Amount*-%** of 6.2 for FY77	6.3 ADVANCED DEVELOPMENT Project - Task Title Funds: Amount*-%** of 6.3 for FY77
FLIGHT DYNAMICS	1L161102AH45-TAI Rsch in Aerodynamics *2265/49%*	1L262209AH76-TAI Aerodynamics Technology *2303/12%* 1L262209AH75-TAX Flight Simulation *1020/5%*	1L263211D157-Task 11 & 12 Advanced Rotor Tech *1780/14%* 1L263211D157-Task 18 Comp Helicopter Analysis *800/6%*
VEHICLE DESIGN	1L161102AH45-TAII Rsch in Propulsion *1030/22%* 1L161102AH45-TAIII Rsch in Structures *1125/24%*	1L262209AH76-TAII Structures Technology *2960/17%* 1L262209AH76-TAIII Propulsion Technology *2915/16%* 1L262209AH76-TAIV Reliability & Maintainability *1830/10%* 1L262209AH76-TAVIII Aircraft Subsystems *440/2%* 1L262209AH76-TAXI Man-Machine Integration *150/1%*	1L263211DB41 Advanced Structures *5391/4%* 1L263201D447 Demonstrator Engines *2774/23%* 1L263201DB72 Propulsion Components *8591/7%*
MILITARY APPLICATION		1L262209AH76-TAV Safety & Survivability *2070/12%* 1L262209AH76-TAVI Mission Support *674/4%* 1L762732AF34 RPV Supporting Technology *1402/7%* 262201DH96 Aircraft Weapons Technology *1586/9%*	1L263209DB33 Cargo Handling Equipment *137/10%* 1L263209D109 Helicopter Anti/Deicing *403/3%*
SUPPORT	1L161102AH45-TAIV Mathematics *65/2%* ILIR (Lab Indep Rsch) *150/3%*	1L262209AH76-TAVII Aircraft Systems Synthesis *1030%5%*	
ADVANCED TECHNOLOGY DEMONSTRATION			1L263213DB36 Rotor System Rsch Aircraft *1999/16%* 1L263212DB74 Tilt Rotor Aircraft *2393/19%* 1L263211D157-Task 17 Advancing Blade Concept *867/7%*

*In Thousands

**Percentages of RTL R&D funds allotted to each identified Project/Tech Area/Task level as applied to total of either 6.1, 6.2 or 6.3 RTL R&D funds.

APPENDIX B
BIBLIOGRAPHY OF PUBLICATIONS AND PRESENTATIONS IN FY77

PAPERS AND PRESENTATIONS

Acurio,* J., and Kailos,* N., Edwards V., "Engine-Airframe Integration – Current Practices and Future Requirements for Army Aircraft," presented at the Project Squid Workshop U.S. Naval Academy, Annapolis, MD, 11-12 May 1977.

Adams,* Richard I., and Kitchens,* Phyllis F., "Simulated and Natural Icing Tests of an Ice Protected UH-1H," presented at the 33rd Annual Forum of the American Helicopter Society, Washington, DC, May 1977.

Alston,* William B., "Nitrile Crosslinked Polyphenylquinoxaline/ Graphite Fiber Composites," NASA TM X-73456, presented at Eighth National Symposium and Technical Conference of the Society for the Advancement of Material and Process Engineering, Seattle, WA, 12-14 Oct. 1976.

Andre,* W. L., guest speaker, 155th Attack Helicopter Co., Presidio, Monterey, 29 Apr. 1977.

Andre,* W. L., and Wong,* J. T., "Logic Model Test Equipment for Maintenance and Training," presented at the Second Biennial Maintenance Training and Aiding Conference in Orlando, FL, May 1977.

Ballhaus,* W. F., and Goorjian, P. M., "Implicit Finite Difference Computations of Unsteady Transonic Flows about Airfoils, Including the Treatment of Irregular Shock Wave Motions," AIAA Paper 77-205, presented at AIAA 15th Aerospace Sciences Meeting, 24-26 Jan. 1977.

Ballhaus,* W. F., and Goorjian, P. M., "Computation of Unsteady Transonic Flows by the Indicial Method," AIAA Paper No. 77-447, presented at the AIAA Dynamics Specialists Meeting, Mar. 1977.

Ballhaus,* W. F., and Goorjian, P. M., "Efficient Solution of Unsteady Transonic Flows about Airfoils," AGARD Structures and Materials Meeting, Lisbon, Portugal, Apr. 1977.

Ballhaus,* W. F., Bailey, F. R., and Frick, J., "Improved Computational Treatment of Transonic Flow About Swept Wings," Proceedings of 13th Meeting of Society for Engineering Science, Vol. 4, Nov. 1976.

Ballhaus,* W. F., Jameson, A., and Albert, J., "Implicit Approximate-Factorization Schemes for the Efficient Solution of Steady Transonic Flow Problems," AIAA Paper No. 77-634, Jun. 1977.

Ballhaus,* W. F., Goorjian, P. M., and Yoshihara, H., "Unsteady Force and Moment Alleviation in Transonic Flow," AGARD CP-227 (Paper No. 14), presented at AGARD Conference on Unsteady Aerodynamics, Ottawa, Canada, Sept. 1977.

Bartlett,* Felton E., Jr., "Hub Force Determination: A New Method for Measuring Rotor-Induced Vibratory Loads Using Fuselage Accelerations and Dynamic Calibration Data," presentation at Third Structures Loads Meeting, Ft. Eustis, VA, Aug. 1977.

*DENOTES RTL EMPLOYEE

Bement, L. J., "RSRA Canopy Explosive Severance/Fracture," presented at Symposium on Explosives and Pyrotechnics, 9th, Philadelphia, PA, 15-16 Sept. 1976, and proceedings Franklin Institute Research Laboratories, 1976.

Biggers, James C., Lee, Albert, Orloff, Kenneth L., and Lemmer,* Opal J., "Measurements of Helicopter Rotor Tip Vortices," AHS Preprint No. 77.33-06, presented at the 33rd Annual National Forum of the AHS, May 1977.

Bill,* R. C., "Fretting of AISI 9310 and Selected Fretting Resistant Surface Treatments," NASA TM X-73,591 Technical Paper to be presented at the Annual Meeting of the American Society of Lubrication Engineers, Montreal, Canada, 3-4, May 1977.

Bill,* Robert C., and Wisander, Donald, "Recrystallization as a Controlling Process in the Wear of Some F.C.C. Metals," Journal Article – Wear, 41, Jan. 1977.

Bingham,* Gene J., "Status of Current Two-Dimensional Helicopter Airfoil Research," Slide presentation for the Helicopter Program Coordinating Meeting, Langley Research Center, 19 Apr. 1977.

Bousman,* William G., "An Interpretation of the Army Standard Hot Day in Operational Terms," Reprint from *Journal of the AHS*, Jul. 1977.

Bratt,* Howard M., "Simulation Aided Field Experimentation," presented at the U.S. Army Operations Research Symposium XV, Fort Lee, VA, 28 Oct. 1976.

Bratt,* Howard M., "(1) *The Tri-Service Commonality Analysis*; (2) The Maintenance Effectiveness Analysis; (3) The Arms Model," lecture at UCLA, 18 Nov. 1976.

Bratt,* Howard M., "Optimizing Logistic Support (ILS) Resources to Support Military Tasks," presented to the Virginia Beach Chapter of the Society of Logistic Engineers, 5 May, 1977.

Bratt,* Howard M., "Optimizing Logistic Support (ILS) Analysis Resources to Support Military Tasks," presented at the 12th International Logistics Symposium, San Diego, CA, 16-17 Aug. 1977.

Brown,* LTC James H., Jr., and Edenborough,* H. Kipling, "Evaluation of the Tilt Rotor Concept–The XV-15's Role," Paper No. 16 AGARD-NATO, Flight Mechanics Panel, Symposium on Rotorcraft Design, 16-19 May 1977.

Burke, LTC J. A., Schmitz,* F. H., Vause,* C. R., "Optimizing Takeoffs of a Heavily Loaded Helicopter," U.S. Army Aviation Digest, May 1977.

Cancro,* Patrick A., Harris, Frank, and Dixon, Peter, "Bearingless Main Rotor System Concept," presented at the Association Aeronautique et Astronuatique de France, Aix-en-Provence, France, 7-9 Sept. 1977.

Carper,* C. H., RTL Structures Program briefed to Mr. Jerome Persh at Structures Apportionment Review, Jul. 1977.

Chen,* Robert T. N., and Talbot,* Peter D., "An Exploratory Investigation of the Effects of Large Variations in Rotor System Dynamics Design Parameters on Helicopter Handling Characteristics in Nap-of-the-Earth Flight," presented at the 33rd Annual National Forum of the American Helicopter Society, Washington, DC, May 1977.

Corliss,* Lloyd D., Greif, Richard K., and Gerde, Ronald M., "An In-Flight Simulation of VTOL Hover Control Concepts," AIAA Paper No. 77-610, Jun. 1977.

Dunn,* R. S., "Aircrew Workload Measurement Requirements and R&D," Triservice and NASA Coordination Working Group Meeting, W-PAFB, Apr. 1977.

Falarski,* Michael J., Wilby, John F., and Aiken, Thomas N., "Augmentor Wing Propulsive-Lift Concept Acoustic Characteristics," AIAA Paper No. 76-79, presented at AIAA 14th Aerospace Sciences Meeting, 26-28 Jan. 1976, reprint from *Journal of Aircraft*, Vol. 13, No. 12, Dec. 1976.

Figge,* I. E., "Composites Development for Army Airmobile Systems," presented to the workshop on the Application of Composites in General Aviation, LRC, Jun. 1977.

George,* Robert E., and Duffy, Vance, "In-Flight Measurement of Aircraft Acoustic Signals," presented at the 23rd International Instrumentation Symposium, 2-5 May 1977, Las Vegas, NV, published in Instrumentation in the Aerospace Industry, Vol. 23.

Gilson, R. D., Dunn,* R. S., and Sun, P., "A Kinesthetic-Tactual Display Concept for Helicopter-Pilot Workload Reduction," Proceedings of the 33rd Forum, American Helicopter Society, Washington DC, May 1977.

Gomez,* James Jr., and Gardner, G. F., "Design and Development of a 3000-hp Roller Gear Transmission," presented at the American Gear Manufacturers Association (AGMA), Aerospace Gearing Committee Meeting, Orlando, FL, 13 Apr. 1977.

Gomez,* James Jr., and Pauze,* Daniel E., "Helicopter Advanced Technology Transmission Components," presented at the American Helicopter Society, Washington, DC, 10-11 May 1977.

Hamed, A., Sheoran, Y., and Tabakoff, W., "Cooling Considerations for Design of a Radial Inflow Turbine," ASME Paper No. 77-gt-82, Dept. of Aerospace Engineering and Applied Mechanics, University of Cincinnati.

Hammond,* C. E., "Recent Experience in the Testing of a Generalized Rotor Aeroelastic Model at Langley Research Center," presented at the European Rotorcraft and Powered Lift Aircraft Forum (AGARD), Bueckenburg, Germany, 20-22 Sept. 1976.

Hammond,* C. E., "Measurement of Subcritical Damping During Wind Tunnel Dynamic Model Tests," graduate seminar at Virginia Polytechnic Institute and State University, Blacksburg, VA, 10 Nov. 1976.

Hammond,* C. E., "Wind Tunnel Testing of Aeroelastically Scaled Helicopter Rotor Models," presented at a graduate seminar, UCLA, 17 Mar. 1977.

Hammond,* C. E., "Helicopter Mechanical Instability Revisited: The Influence of a Blade Damper Failure," presented at a seminar at Pennsylvania State University, State College, PA, 16 Jun. 1977.

Haselbauer,* Phillip, "Low Velocity Impact Resistance of Advanced Composite Drive Shafts," presented at the AIAA/ASME Symposium on Aircraft Composites, San Diego, CA, Mar. 1977.

Hoad,* Danny R., "Externally Blown Flap Impingement Parameter," Powered-Lift Aerodynamics and Acoustics Conference, Langley Research Center, May 1976.

Hoad,* Danny R., "Propulsion Characteristics Affecting the Aerodynamic Performance of an Externally Blown Flap Transport Model," *Journal of Aircraft*, Vol. 13, No. 8, Aug. 1976.

Hoad,* Danny R., and Young,* Warren H., Jr., "Velocity Measurements About a NACA 0012 Airfoil With a Laser Velocimeter – V/STOL Tunnel," published in LRC Aeronautics Directorate Weekly Brief, Jun. 1977.

Hodges,* Dewey H., "An Experimental-Theoretical Correlation Study of Non-Linear Bending and Torsion Deformations of a Cantilever Beam," *Journal of Sound and Vibration*, 22 Feb. 1977.

Hodges,* Dewey H., "A Simplified Algorithm for Determining the Stability of Linear Systems," *AIAA Journal*, Vol. 15, No. 3, 3 Mar. 1977.

Hodges,* Dewey H., "Air and Ground Resonance Analysis of Helicopters with a Bearingless Main Rotor System," Ames Directorate Special Report, May 1977.

Hodges,* Dewey H., and Ormiston,* Robert A., "Stability of Hingeless Rotor Blades in Hover with Pitch-Link Flexibility," *AIAA Journal*, Vol. 15, No. 4, Apr. 1977.

Hogg,* G. William, and Reis, J. J., "Helicopter Gearbox Failure Prognosis," presented at the AIAA/SA 13th Propulsion Conference, Orlando, FL, 11-13 Jul. 1977.

Huston, Robert J., Jenkins, Julian L., Jr., and Shipley,* John L., "The Rotor Systems Research Aircraft – A New Step in the Technology and Rotor System Verification Cycle," presented at the AGARD Flight Mechanics Panel Symposium on Rotorcraft Design, Ames Research Center, 16-19 May 1977.

Immen,* F. H., "Advanced Structures Technology in Army Helicopters," presented at ASME Conference, New York City, 7 Dec. 1976.

Immen,* F. H., "U.S. Army AVRADCOM Technology Base Structures Program," presented at Advanced Planning Briefing for Industry at St. Louis, MO, 14 Sept. 1977.

Johnson,* Wayne, "Optimal Control Alleviation of Tilting Proprotor Gust Response," *Journal of Aircraft*, Vol. 14, No. 3, Mar. 1977.

Johnson,* Wayne, and Gupta, Narendra K., "Transfer Function and Parameter Identification Methods for Dynamic Stability Measurement," Preprint No. 77.33-35, presented at the 33rd Annual Forum of the AHS, May 1977.

Kitchens,* Phyllis F., "Simulated and Natural Icing Tests of a Cyclic Electrothermal Helicopter Ice Protection System," presented at the American Helicopter Society 33rd Annual National Forum, Washington, DC., 9-11 May 1977.

Koenig, David G., Aiken, Thomas N., and Aoyagi, Kiyoshi, "Large-Scale V/STOL Testing," AIAA paper No. 77-586, presented at AIAA/NASA V/STOL Conference, Palo Alto, CA, 6-8 Jun. 1977.

Law,* Dr. Harold Y. H., "A Macroscopic Modeling Concept for Logistic Policy Guideline of an Airmobile Combat System," presented at the 15th Army Operations Research Symposium, Ft. Lee, VA, 26-29 Oct. 1976.

Law,* Dr. Harold Y. H., "Application of Operations Research in a Research and Development Environment," presented at the Student Chapter of SIAM, Washington University, St. Louis, MO, 15 Dec. 1976.

Levine,* S. R., and Clark, J. S., "Thermal Barrier Coatings – A Near Term, High Payoff Technology," presented at the Workshop on Ceramics for Energy Conversion Systems sponsored by ERDA, Orlando, FL, NASA TM X-73586, Jan. 1977.

Loendorf,* David D., "The Role of Microprocessors in Specialized Structural Analysis," presented at the ASME Conference (Annual Winter Meeting), New York, NY, Dec. 1976.

Lowell, Carl E., Grisaffe, Salvatore J., and Levine,* Stanley R., "Toward More Environmentally Resistant Gas Turbines: Progress in NASA-Lewis Programs," presented at the Third Conference on Gas Turbine Materials in a Marine Environment, Bath, England, NASA TM X-73499, Sept. 1976.

Mantay,* Wayne R., "Status and Progress of the Advanced Tip Shape Program," presented to BG Story C. Stevens, Langley Research Center, 3 Mar. 1977.

Mantay,* Wayne R., "Status of Advanced Airfoils and Advanced Tip Shapes," slide presentation for the Lowey Aeronautics and Space Engineering Board, Aeronautics Assessment Committee, Langley Research Center, 14 Apr. 1977.

Mantay,* Wayne R., and Rorke, J. B., "The Evolution of the Variable Geometry Rotor," presented at the AHS Mideast Region Symposium on Rotor Technology, Essington, PA, 11-13 Aug. 1976.

Mantay,* Wayne R., Holbrook, G. Thomas, Campbell, Richard L., and Tomaine,* Robert L., "Helicopter Response to an Airplane's Trailing Vortex," presented at the AIAA 3rd Atmospheric Flight Mechanics Conference, Arlington, TX, 7-9 Jun. 1976.

Mantay,* Wayne R., Holbrook, G. Thomas, Campbell, Richard L., and Tomaine,* Robert L., "Helicopter Response to an Airplane's Trailing Vortex," *Journal of Aircraft*, Apr. 1977.

Mayerjak, R. J., and Singley,* G.T., III, "Composite Rotor Hub," presented at the 33rd Annual National Forum of the American Helicopter Society, Washington, DC, 9-11 May 1977.

Mayerjak, R. J., and Singley,* G.T., III, "Composite Rotor Hub, Part II," presented at the American Helicopter Society on Helicopter Structures Technology, Ames Research Center, Moffett Field, CA, 16-18 Nov. 1977.

Mazza,* L. T., "Composite Tail Section for AH-1G Helicopter and Multi-Tubular Spar (MTS) Main Rotor Blade for the AH-1G," presented to the Army/Navy/NASA Composites Fabrication Program Review, Marietta, GA, Sept. 1977.

McCroskey,* W. J., "Some Current Research in Unsteady Fluid Dynamics," Freeman Scholar Award Lecture presented to the Winter Annual Meeting of the American Society of Mechanical Engineers, New York, NY, Mar. 1977.

Merkley,* Donald J., "The Second Generation Comprehensive Helicopter Analysis System," *Army Research and Development News Magazine*, Sept. 1976.

Moen,* Gene C., DiCarlo, Daniel J., and Yenni, Kenneth R., "A Study to Determine the Characteristic Shapes of Helicopter Visual Approach Profiles," *Journal of the American Helicopter*, Apr. 1977.

Moore,* Frederick L., and Occhiato, John J., "The Basic Flying Characteristics of the Rotor Systems Research Aircraft," presented at the 33rd Annual National Forum of the American Helicopter Society, Washington, DC, 9-11 May 1977.

Mort, Kenneth W., Soderman,* Paul T., and Eckert,* William T., "Improving Large-Scale Testing Capability by Modifying the 40- by 80-Foot Wind Tunnel," presented at AIAA/NASA Ames V/STOL Conference, Palo Alto, CA, 6-8 Jun. 1977.

Ng,* G. Shek, "Thermal and Structural Analysis of Helicopter Transmission Housings Using NASTRAN," presented at the NASTRAN Colloquium, Ames Research Center, Moffett Field, CA, Oct. 1976.

Ng,* G. Shek, "Thermal and Structural Analysis of Helicopter Transmission Housings Using NASTRAN," presented at the American Helicopter Society in Hampton, VA, Nov. 1976.

Phelps,* Arthur E., III, and Johnson, Joseph L., Jr., "Summary of Low-Speed Aerodynamic Characteristics of Upper-Surface-Blown Jet-Flap Configurations," Powered-Lift Aerodynamics and Acoustics Conference, Langley Research Center, May 1976.

Roderick,* George L., "Fatigue Damage and Boron Epoxy Laminate Constant Amplitude Loading," presented at the ASTM Symposium, Denver, CO, 15-16 Nov. 1976.

Roderick,* George L., "Fatigue and Fracture of Composite Materials," slide presentation for the Lowey Aeronautics and Space Engineering Board, Aeronautics Assessment Committee, Langley Research Center, 15 Apr. 1977.

Roderick,* George L., "Fatigue and Fracture of Composite Materials With Application to Bearingless Main Rotor of the Helicopter," slide presentation for the Helicopter Program Coordinating Meeting, Langley Research Center, 19 Apr. 1977.

Roderick,* George L., "Research on Fatigue of Composites at Langley Research Center," presentation at Third Structures Loads Meeting, Fort Eustis, VA, 25 Aug. 1977.

Roderick*, George L., and Sun, C. T., "Improvements of Fatigue Life Under Boron/Epoxy Laminates by Heat Treatment Under Loads," presented at ASTM Symposium, Denver, CO, 15-16 Nov. 1976.

Roderick,* G. L., and Whitcomb, J. D., "Fatigue Damage of Notched Boron/Epoxy Laminates Under Constant Amplitude Loading," presented at ASTM Symposium on Fatigue of Filamentary Composites, Langley Research Center, 15-18 Nov. 1976.

Schmitz,* Frederic H., "Research Proposal for Helicopter Noise Detection Study," Joint Inst. for Aeronautics & Acoustics, Stanford University, Palo Alto. CA Jul. 1977.

Schmitz,* F. H., and Boxwell,* D. A., "In-Flight Far-Field Measurement of Helicopter Impulsive Noise," *AHS Journal*, Oct. 1976.

Schmitz,* F. H., and Yu,* Yung, H., "Theoretical Modeling of Speed Helicopter Impulsive Noise," Paper No. 54, Third European Rotorcraft and Powered Lift Aircraft Forum, 7-9 Sept. 1977.

Shallcross,* COL G. W., "Command Briefing," presented to the Aviation Safety Officers class, Fort Rucker, AL, 1 Jun. 1977.

Shallcross,* COL G. W., "Command Briefing," presented at the Eustis Directorate Ladies Day, Fort Eustis, VA, 28 Jun. 1977.

Shallcross,* COL G. W., "Command Briefing," presented to the 25 Math and Science Students from the York High School, at Fort Eustis, VA, 10 Nov. 1976.

Shallcross,* COL G. W., "Command Briefing," presented to 25 Math and Science students from the Tabb High School, at Fort Eustis, VA, 12 Nov. 1976

Shallcross,* COL G. W., "Command Briefing," presented to 50 ROTC students from Hampton Institute, at Fort Eustis, VA, 19 Nov. 1976.

Shallcross,* COL G. W., "Command Briefing," presented to Congressman Paul Trible at Fort Eustis, VA, 10 Dec. 1976.

Shallcross,* COL G. W., "Command Briefing," presented to six officers from the Armed Forces Staff College, Norfolk, VA, at Fort Eustis, VA, 11 Jan. 1977.

Shallcross,* COL G. W., "Command Briefing," presented at the Eustis Directorate Organization Day at Fort Eustis, VA, 25 Feb. 1977.

Shallcross,* COL G. W., "Command Briefing," presented to the Naval Helicopter Association Meeting, Norfolk, VA, 9 Feb. 1977.

Shallcross,* COL G. W., "Command Briefing," presented to the Gloucester Rotary Club, Gloucester, VA, 17 Feb. 1977.

Shallcross,* COL G. W., "Command Briefing," presented to the Army Aviation Safety Officers Class, Fort Rucker, AL, 8 Mar. 1977.

Shallcross,* COL G. W., "Command Briefing," presented to 68 representatives from the Canadian Land Forces Command and Staff College, Kingston, Ontario, at Fort Eustis, VA, 11 Mar. 1977.

Shallcross,* COL G. W., "Command Briefing," presented to 25 Transportation Officers Advanced Course students and six instructors, Fort Eustis, VA, 14 Apr. 1977.

Shallcross,* COL G. W., "Command Briefing," presented to representatives from the 6th Cavalry Brigade, at Fort Eustis, VA, 15 Apr. 1977.

Shallcross,* COL G. W., "Command Briefing," presented to the Aerospace Writers of America, Annual Meeting, San Francisco, CA, 4 May 1977.

Shallcross,* COL G. W., "Command Briefing," presented to the Lancaster Rotary Club, Lancaster, PA, 25 May 1977.

Shallcross,* COL G. W., "Command Briefing," presented to 45 students and 5 instructors from the Piarist Fathers Group, Devon, PA, 13 June 1977.

Shallcross,* COL G. W., "Command Briefing," presented at the 52nd Annual Meeting of the Virginia Engineering Technical Society, Williamsburg, VA, 18 Jun. 1977.

Singley,* George T., Jr., "Command Briefing," presented to the members of the Australian Embassy, Fort Eustis, VA, 1 Apr. 1977.

Singley,* George T., Jr., "Command Briefing," presented to the Transportation Officers Advance Course 501-76, Fort Eustis, VA, 17 Aug. 1976.

Singley,* George T., III, and Mayerjak, Robert J., "Fail-Safe Composite Rotor Hub," presented at the Army Symposium on Solid Mechanics, South Yarmouth, MA, 14-16 Sept. 1976.

Sleeman, William C., Jr., and Phelps,* Arthur E., III, "Upper-Surface-Blowing Flow-Turning Performance," presented at 1976 Conference on Powered-Lift Aerodynamics and Acoustics, Langley Research Center, May 1976.

Stanton,* Russell O., "Rotary Wing RPV Program," presented to the Deputy for Communication Target Acquisition to the Assistant Secretary of the Army for R&D, Washington, DC, 16 Mar. 1977.

Swindlehurst,* Carl E., Jr., "Development of the Composite Bearingless Main Rotor System," presented at the AHS Mideast Region Symposium on Rotor Technology, Essington, PA, 11-13 Aug. 1976.

Tabakoff, W., Hosny, W., and Hamed, A., "Computation of the Temperature Distribution in Cooled Radial Inflow Turbine Guide Vanes," ASME Paper 77-GT-83, presentation 27-31 Mar. 1977.

Taylor,* Marion K., "Safety and Survivability Overview with Emphasis on Safety," presented to the Army Aviation Safety Officers Class, Fort Rucker, AL, 8 Mar. 1977.

Tomaine,* Robert L., "The Effect of Pilot Control Input Shape on the Identification of Six Degree-of-Freedom Stability and Control Derivatives of a Transport Helicopter," Thesis submitted to GWU in partial fulfillment of the requirements for a Degree of Master of Science, Dec. 1976.

Walton, W. C., Jr., Hedgepeth, R. K., and Bartlett,* F. D., Jr., "Report on Rotor Systems Research Aircraft Design for Vibrations," presented at the SAE 1976 Aerospace Engineering and Manufacturing Meeting, San Diego, CA, 30 Nov. – 2 Dec. 1976.

Weller,* William H., "Wind Tunnel Testing of Aeroelastically-Scaled Helicopter Rotor Models," lecture presented to AIAA Student Chapter of University of Tennessee, 14 Apr. 1977.

White, Bill P., and Weller,* William H., "The Flexhinge Rotor," presented at American Helicopter Society Mideast Region Symposium on Rotor Technology, Essington, PA, 11-13 Aug. 1976.

Wilson,* John C., "Drag Reduction Feature for Armed Attack Helicopters," presented to BG Story C. Stevens, Langley Research Center, 3 Mar. 1977.

Wilson,* John C., and Phelps,* Arthur E., "4- by 7-Meter (V/STOL) Tunnel Investigation of Drag Reduction of Army Helicopter Rocket Launcher System," research briefing for Director of Aeronautics, Langley Research Center, 11 Aug. 1977.

Wong,* J. T., "Some Laboratory's Mathematical Problems," presented at the 42nd Meeting of Army Mathematics Steering Committee at Watertown, MA, 4-5 Nov. 1976.

Young,* Harvey and Simon,* Duane, "ABC Rotor Program," presented to the AGARD Flight Mechanics Panel, Moffett Field, CA, 18 May 1977.

Yu,* N. J., Seebass, A. R., and Ballhaus,* W. F., "An Implicit Shock-Fitting Scheme for Unsteady Transonic Flow Computations," AIAA Paper No. 77-633, AIAA Computational Fluid Dynamics Conference, Albuquerque, NM, Jun. 1977.

RTL REPORTS

Arents,* Donald N., "An Assessment of the Hover Performance of the XH-59A Advancing Blade Concept Demonstration Helicopter," USAAMRDL TN-25, May 1977.

Atencio,* Adolph, Jr., "The Effect of Forward Speed on J85 Engine Noise from Suppressor Nozzles as Measured in the NASA-Ames 40- by 80-Foot Wind Tunnel," NASA TN D-8426, Feb. 1977.

Ballhaus,* W. F., Jameson, A., and Albert, J., "Implicit Approximate-Factorization Schemes for the Efficient Solution of Steady Transonic Flow Problems," NASA TM X-73,202, Jan. 1977.

Bill,* R. C., "Fretting of AISI 9310 and Selected Fretting Resistant Surface Treatments," NASA TM X-73,591, May 1977.

Bobula*, George A., and Lottig, Roy A., "Inlet Reynolds Number and Temperature Effects on the Steady-State Performance of a TFE731-2 Turbofan Engine," NASA TM X-3537, May 1977.

Brown,* Thomas J., and Powell, Clemans, A., "Aircraft-Noise Synthesizer," NASA Tech Brief LAR-11358, Jun. 1977.

Carlson,* R. M., "Technical Risk Assessment, OH-58 Mast Mounted Sight," ASRO Report 77-1, Jan. 1977.

Carr,* Lawrence W., McAllister,* Kenneth W., and McCroskey,* William J., "Analysis of the Development of Dynamic Stall Based on Oscillating Airfoil Experiments," NASA TN D-8382, Jan. 1977.

Corliss,* Lloyd D., and Talbot, Peter D., "A Failure Effect-Simulation of a Low Authority Flight Control Augmentation System on a UH-1H Helicopter," NASA TM-73,258, Aug. 1977.

Dixon, G. V., Barringer, S. R., Gray,* C. E., Jr., and Leatherman, A. D., "A Tabulation of Pipe Length to Diameter Ratios as a Function of Mach Number and Pressure Ratios for Compressible Flow," NASA TM X-72,756, Oct. 1975.

Eckert,* William T., Mort, Kenneth W., and Jope, Jean, "Aerodynamic Design Guidelines and Computer Program for Estimation of Subsonic Wind Tunnel Performance," NASA TN D-8243, Oct. 1976.

Evans,* Timothy D., Vichness,* Jules A., "Helicopter Cargo Systems Effectiveness Analysis."

Farassat, F., and Brown,* T. J., "A New Capability for Predicting Helicopter Rotor and Propeller Noise Including the Effect of Forward Motion," NASA TM X-74,037, Jun. 1977.

Freeman,* Carl E., and Yeager,* William T., Jr., "Wind-Tunnel Investigation of an Unpowered Helicopter Fuselage Model With V-Type Empennage," NASA TM X-3476, Mar. 1977.

Haas,* Jeffrey, E., Kofskey, Milton G., Hotz, Glen M., and Futral, Samuel M., Jr., "Cold-Air Performance of a Tip Turbine Designed to Drive a Lift Fan – I – Baseline Performance," NASA TM X-3452, Dec. 1976.

Haas,* Jeffrey E., Kofskey, Milton G., Hotz, Glen M., and Futral, Samuel M., Jr., "Cold-Air Performance of a Tip Turbine Designed to Drive a Lift Fan – II – Partial Admission," NASA TM X-3481, Feb. 1977.

Haas,* Jeffrey, E., and Kofskey, Milton G., "Cold-Air Performance of a 12.766-Centimeter-Tip-Diameter Axial-Flow Cooled Turbine II-Effect of Air Injection on Turbine Performance," NASA TP 1018, Aug. 1977.

Hodder,* Brent K., "Further Studies of Static to Flight Effects on Fan Tone Noise Using Inlet Distortion Control for Source Identification," NASA TM X-73,183, Dec. 1976.

Hosier,* Robert N., "A Comparison of Two Independent Measurements and Analyses of Jet Aircraft Flyover Noise," NASA TN D-8379, Jun. 1977.

Huffman, Jarrett K., Fox, Charles H., Jr., and Satterthwaite, Robert E., "Longitudinal and Lateral- Directional Static Aerodynamic Characteristics of an Unpowered Escape System Extraction Rocket Model With Attached Launch Tubes," NASA TM X-74,012, May 1977.

Johnson,* Wayne, "The Influence of Pitch-Lag Coupling on the Predicted Aeroelastic Stability of the XV-15 Tilting Proprotor Aircraft," NASA TM X-73,213, Feb. 1977.

Johnson,* Wayne, "Helicopter Optimal Descent and Landing after Power Loss," NASA TM 73,244, May 1977.

Johnson,* Wayne, "Flap/Lag/Torsion Dynamics of a Uniform, Cantilever Rotor Blade in Hover," NASA TM 73,248, May 1977.

Johnson,* Wayne, "Calculated Dynamic Characteristics of a Soft-Inplane Hingeless Rotor Helicopter," NASA TM 73,262, Jun. 1977.

Johnson,* Wayne, "Aeroelastic Analysis for Rotorcraft in Flight or in a Wind Tunnel," NASA TN D-8515, Jul. 1977.

Johnson,* Wayne, "Development of a Transfer Function Method for Dynamic Stability Measurement," NASA TN D-8522, Jul. 1977.

Klassen, Hugh A., Wood,* Jerry R., and Schumann,* Lawrence F., "Experimental Performance of a 16.10-Centimeter-Tip-Diameter Sweptback Centrifugal Compressor Designed for a 6:1 Pressure Ratio," NASA TM X-3552, Jun. 1977.

Kunz,* Donald L., "Effects of Unsteady Aerodynamics on Rotor Aeroelastic Stability," NASA TM 78,434, Sept. 1977.

Levine,* Stanley R., "Hot Hardness of Nickel-Rich Nickel-Chromium-Aluminum Alloys," NASA TM X-3429, Oct. 1976.

Levine,* Stanley R., "Reaction Diffusion in the Nickel-Chromium-Aluminum and Cobalt-Chromium-Aluminum Systems," NASA TN D-8383, Feb. 1977.

Levine,* S. R., and Clark, J. S., "Thermal Barrier Coatings – A Near Term, High Payoff Technology," NASA TM X-73,586, Jan. 1977.

Lowell, Carl E., Grisaffe, Salvatore J., and Levine,* Stanley R., "Toward More Environmentally Resistant Gas Turbines: Progress in NASA-Lewis Programs," NASA TM X-73,499, Sept. 1976.

Meitner,* Peter L., and Hippensteele, Steven A., "Experimental Flow Coefficients of a Full-Coverage Film-Cooled-Vane Chamber," NASA TP 1036, Sept. 1977.

Merritt,* E. V., "Analysis of Vulnerability Reduction Modifications for Army Aircraft (U)," USAAMRDL TN-23, Oct. 1976 (CONFIDENTIAL)

Merritt,* E. V., Peterson,* W. L., and Bywaters,* R. E., "Vulnerability of Helicopters to Fragmenting Munitions (U)," USAAMRDL TN-24, Nov. 1976 (CONFIDENTIAL)

Merritt,* E. V., Peterson,* W. L., Bywaters,* R. E., and Shostak,* J., "Vulnerability of the OH-6A Helicopter to Impacting Ground-Fired Projectiles (U)," USAAMRDL TM-8, Oct. 1976. (CONFIDENTIAL)

Mineck,* Raymond E., "Tail Contribution to the Directional Aerodynamic Characteristics of a 1/6 Scale Model of the Rotor Systems Research Aircraft With a Tail Rotor," NASA TM X-3501, May 1977.

Mineck,* Raymond E., "Effect of Rotor Wake on Aerodynamic Characteristics of a 1/6-Scale Model of the Rotor Systems Research Aircraft," NASA TM X-3548, Sept. 1977.

Mineck,* Raymond E., and Freeman,* Carl E., "Airframe, Wing, and Tail Aerodynamic Characteristics of a 1/6-Scale Model of the Rotor Systems Research Aircraft With the Rotors Removed," NASA TN D-8456, May 1977.

Mineck,* Raymond E., and Freeman,* Carl E., "Aerodynamic Characteristics of a 1/6-Scale Powered Model of the Rotor Systems Research Aircraft," NASA TM X-3489, Jun. 1977.

Moen,* Gene C., DiCarlo, Daniel J., and Yenni, Kenneth R., "A Parametric Analysis of Visual Approaches for Helicopters," NASA TN D-8275, Dec. 1976.

Noonan,* Kevin W., and Bingham,* Gene J., "Two-Dimensional Aerodynamic Characteristics of Several Rotorcraft Airfoils at Mach Numbers from 0.35 to 0.90," NASA TM X-73990, Jan. 1977.

Page, V. Robert, Eckert,* William T., and Mort, Kenneth W., "An Aerodynamic Investigation of Two 1.83-Meter-Diameter Fan Systems Designed to Drive a Subsonic Wind Tunnel," NASA TM 73,175, Sept. 1977.

Phelps,* Arthur E., III, "Static and Wind-On Tests of an Upper-Surface-Blown Jet-Flap Nozzle Arrangement For Use on the Quiet Clean Short-Haul Experimental Engine (QCSEE)," NASA TN D-8476, Jun. 1977.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for the National Transonic Facility for a 9% Nickel Tunnel Shell – Finite Difference Analysis of Cone/Cylinder Junction," Vol. 1, NASA TM X-73,956-1, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr, Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for National Transonic Facility for a 9% Nickel Tunnel Shell – Finite Element Analysis of Corners Nos. 3 and 4," Vol. 2, NASA TM X-73,956-2, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for National Transonic Facility for a 9% Nickel Tunnel Shell – Finite Element Analysis of Plenum Region Including Side Access Reinforcement, Side Access Door and Angle of Attack Penetration," Vol. 3, NASA TM X-73956-3, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for National Transonic Facility for a 9% Nickel Tunnel Shell – Thermal Analysis," Vol. 4, NASA TM X-73,956-4, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for National Transonic Facility for a 9% Nickel Tunnel Shell – Finite Element and Numerical Integration Analyses of the Bulkhead Region," Vol. 5, NASA TM X-73,956-5, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for National Transonic Facility for a 9% Nickel Tunnel Shell – Fatigue Analysis," Vol. 6, NASA TM X-73,956-6, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for National Transonic Facility for a 9% Nickel Tunnel Shell – Special Studies," Vol. 7, NASA TM X-73,956-7, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for National Transonic Facility for a 304 Stainless Steel Tunnel Shell – Finite Difference Analysis of Cone/Cylinder Junction," Vol. 1S, NASA TM X-73,957-1, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for National Transonic Facility for a 304 Stainless Steel Tunnel Shell – Finite Element Analysis of Corners Nos. 3 and 4," Vol. 2S, NASA TM X-73,957-2, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for National Transonic Facility for a 304 Stainless Steel Tunnel Shell – Finite Element Analysis of Plenum Region Including Side Access Reinforcement, Side Access Door and Angle of Attack Penetration," Vol. 3S, NASA TM X-73,957-3, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for National Transonic Facility for a 304 Stainless Steel Tunnel Shell – Thermal Analysis," Vol. 4S, NASA TM X-73,957-4, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for National Transonic Facility for a 304 Stainless Steel Tunnel Shell – Finite Element and Numerical Integration Analyses of the Bulkhead Region," Vol. 5S, NASA TM X-73,957-5, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRc Design Analysis Report for National Transonic Facility for a 304 Stainless Steel Tunnel Shell – Fatigue Analysis," Vol. 6S, NASA TM X-73,957-6, Sept. 1976.

Ramsey, J. W., Jr., Taylor, J. T., Wilson, J. F., Gray,* C. E., Jr., Leatherman, A. D., Rooker, J. R., and Allred, J. W., "LaRC Design Analysis Report for National Transonic Facility for a 304 Stainless Steel Tunnel Shell – Special Studies," Vol. 7S, NASA TM X-73,957-7, Sept. 1976.

Roderick,* G. L., and Whitcomb, J. D., "Fatigue Damage of Notched Boron/Epoxy Laminates Under Constant Amplitude Loading," NASA TM X-73,994, Dec. 1976.

Scheiman, James, and Hoad,* Danny R., "Investigation of Blade Impulsive Noise on a Scaled Articulated Rotor System," NASA TM X-3528, Jun. 1977.

Schumann,* Lawrence F., "Fortran Program for Calculating Leading- and Trailing-Edge Geometry of Turbomachine Blades," NASA TM X-73,679, Jun. 1977.

Schwartzberg,* Milton A., Smith,* Dr. Roger L., Chappell,* David P., "Single-Rotor Helicopter Design and Performance Estimation Programs Volume I-Methodology," SRIO Report No. 77-1, Jun. 1977.

Soderman,* Paul R., and Page, V. Robert, "Acoustic Performance of Two 1.83-Meter-Diameter Fans Designed for a Wind-Tunnel Drive System," NASA TP 1008, Aug. 1977.

Talbot,* Peter D., and Corliss,* Lloyd D., "A Mathematical Force and Moment Model of a UH-1H Helicopter for Flight Dynamics Simulations," NASA TM 73,254, Jun. 1977.

Tomaine,* Robert L., "Flight Data Identification of Six Degree-of-Freedom Stability and Control Derivatives of a Large "Crane" Type Helicopter," NASA TM X-73,958, Sept. 1976.

Wilson,* John C., Freeman,* Carl E., and Stroub,* Robert, "Wind-Tunnel Investigation of Full-Scale Semispan Helicopter Wings With Several Missile Stores," NASA TM SX-3543, May 1977.

Yeager,* William T., Jr., and Mantay,* Wayne R., "Correlation of Full-Scale Helicopter Rotor Performance in Air With Model-Scale Freon Data," NASA TN D-8328, Nov. 1976.

CONTRACT REPORTS

Adams, K. M., and Lucas, J. J., "Study to Investigate Design, Fabrication and Test of Low Cost Concepts for Large Hybrid Composite Helicopter Fuselage, Phase II," Sikorsky Aircraft Div., NASA CR-145167, Structures Laboratory, Apr. 1977.

Anto, A., "Small Turbine Advanced Gas Generator (STAGG) Volume I, Design (U)," Avco Lycoming Div., USAAMRDL TR-76-26A, Applied Technology Laboratory, Mar. 1977. (CONFIDENTIAL)

Anto, A., "Small Turbine Advanced Gas Generator (STAGG), Volume II, Fabrication and Test (U)," Avco Lycoming Div., USAAMRDL TR-76-26B, Applied Technology Laboratory, Apr. 1977. (CONFIDENTIAL)

Artman, M. R., "Mini-RPV Communication Jammer Demonstration Program," E-Systems Inc., Melpar Div., USAAMRDL TR-77-11, Applied Technology Laboratory, Jun. 1977.

Balcerak, John C., "Parametric Study of the Noise Produced by the Interaction of the Main Rotor Wake With the Tail Rotor," Rochester Applied Science Associates, Inc., NASA CR-145001, Structures Laboratory, Jul. 1976.

Barrett, L. D., "Small Hardware Design for Ease of Maintenance and Inspection," Boeing Vertol Co., USAAMRDL TR-76-31, Applied Technology Laboratory, Mar. 1977.

Bielawa, Richard L., "Aeroelastic Analysis for Helicopter Rotor Blades With Time-Variable Nonlinear Structural Twist and Multiple Structural Redundancy-Mathematical Derivation and Program User's Manual," United Technologies Research Center, NASA CR-2638, Structures Laboratory, Oct. 1976.

Bielawa, Richard L., Cheney, Marvin C., Jr., and Novak, Richard C., "Investigation of a Bearingless Helicopter Rotor Concept Having a Composite Primary Structure," United Technologies Research Center, NASA CR-2657, Structures Laboratory, Oct. 1976.

Blackwell, R. H., "Investigation of the Compliant Rotor Concept," Sikorsky Aircraft Div., USAAMRDL TR-77-7 Applied Technology Laboratory, Jun. 1977.

Blewitt, Stephen J., "Product Improvement Program Evaluation," Boeing Vertol Co., USAAMRDL TR-77-17, Applied Technology Laboratory, Jun. 1977.

"Predesign Study for an Aero/Acoustic Research Rotor System," Vol. I, Boeing Vertol Co., NASA CR-145017, Structures Laboratory, Sept. 1976.

"Predesign Study for an Aero/Acoustic Research Rotor System," Vol. II, Boeing Vertol Co., NASA CR-145018, Structures Laboratory, Sept. 1976.

Bowes, M., Giansante, N., Bossler, R., Jr., and Berman, A., "Helicopter Transmission Vibration and Noise Reduction Program," Kaman Aerospace Corp., USAAMRDL TR-77-14, Applied Technology Laboratory, Jun. 1977.

"Gondola System for Helicopter Transport of External Cargo," Brooks & Perkins, USAAMRDL TR-77-28, Applied Technology Laboratory, Sept. 1977.

Campbell, R., Shefrin, J., Simpson, L., Solak, B. J., and Wilson, G., "Heavy Lift Helicopter – Cargo Handling ATC Program, Vol. III Results of Tests, Inspections, and Evaluations," Boeing Vertol Company, USAAMRDL TR-74-97C, Applied Technology Laboratory, Oct. 1976.

Cronkhite, James D., and Berry, Victor L., "Correlation of AH-1G Airframe Test Data with a NASTRAN Mathematical Model," Bell Helicopter Textron, NASA CR-145119, Structures Laboratory, Feb. 1976.

Cronkhite, James D., Wilson, Henry E., and Berry, Victor L., "Correlation of AH-1G Helicopter Flight Vibration Data and Tailboom Static Test Data with NASTRAN Results," Bell Helicopter Textron, NASA CR-145120, Structures Laboratory, Feb. 1976.

Dahlberg, D. E., and Kitts, D. L., "Limited Design, Fabrication and Test of a Small Turbine Advanced Gas Generator (STAGG), Volume I – Gas Generator Program (U)," Pratt & Whitney Aircraft, USAAMRDL TR-76-20A, Applied Technology Laboratory, Feb. 1977. (CONFIDENTIAL)

Dahlberg, D. E., and Kitts, D. L., "Limited Design, Fabrication, and Test of a Small Turbine Advanced Gas Generator (STAGG), Volume II – Derivative Turboshaft Engine Analyses (U)," Pratt & Whitney Aircraft, USAAMRDL TR-76-20B, Applied Technology Laboratory, Feb. 1977. (CONFIDENTIAL).

DeBolt, Harold E., and Robey, Raymond J., "A Study to Improve the Mechanical Properties of Silicon Carbide Ribbon Fibers," Avco Corp., NASA CR-145033, Structures Laboratory, Aug. 1976.

De Paul, R., Jr., Dingle, L. A., and Tomko, R. E., "Final Report for LOGMOD Diagnostic Test Set and Demonstrator," Detex Systems, Inc., ASRO Report 77-2, Advanced Systems Research Office, Jun. 1977.

Doman, G., Tartanzanin, F., Jr., and Shaw, J., Jr., "Investigation of Aeroelastically Adaptive Rotors," USAAMRDL TR-77-3, Boeing Vertol Co., Applied Technology Laboratory, May 1977.

Due, H. F., Jr., Rogo, C., Koster, C. L., and Jasas, G. B., "Advanced Small Axial Turbine Technology," USAAMRDL TR-77-1, Teledyne CAE, Applied Technology Laboratory, May 1977.

Dvorak, Frank A., Maskew, Brian, and Woodard, Frank A., "Investigation of Three-Dimensional Flow Separation on Fuselage Configurations," Analytical Methods, Inc., USAAMRDL TR-77-4, Applied Technology Laboratory, Mar. 1977.

Flannelly, William G., Bartlett, Felton D., Jr., and Forsberg, Thomas W., "Laboratory Verification of Force Determination, a Potential Tool for Reliability Testing," Kaman Aerospace Corp., USAAMRDL TR-76-38, Applied Technology Laboratory, Jan. 1977.

Forsyth, R. W., and Forsyth, J. P., "Helicopter Ground Mobility System (HGMS) Concept Formulation and Selection," Vehicle Systems, USAAMRDL TR-77-35, Applied Technology Laboratory, Sept. 1977.

Francis, P. H., Walrath, D. E., Sims, D. F., and Weed, D. N., "Biaxial Fatigue Loading of Notched Composites," Southwest Research Institute, NASA CR-145198, Structures Laboratory, 24 Jun. 1977.

Frint, Harold K., "Design Selection Tests for TRAC Retraction Mechanism," Sikorsky Aircraft Div., USAAMRDL TR-76-43, Applied Technology Laboratory, Jan. 1977.

Fukushima, T., and Dadone, L. U., "Comparison of Dynamic Stall Phenomena for Pitching and Vertical Translation Motions," Boeing Vertol Co., NASA CR-2793, Structures Laboratory, Jul. 1977.

Gardner, G. F., and Cormier, K. R., "3000-HP Roller Gear Transmission Development Program, Volume I-Summary Report," Sikorsky Aircraft Div., USAAMRDL TR-73-98A, Applied Technology Laboratory, Jan. 1977.

Gardner, G. F., Cormier, K. R., and Trustee, B., "3000-HP Roller Gear Transmission Development Program Volume VI-Reliability and Maintainability Report," Sikorsky Aircraft Div., USAAMRDL TR-73-98f, Applied Technology Laboratory, Jan. 1977.

Hamed, A., Baskharone, E., and Tabakoff, W., "A Numerical Study of the Temperature Field in a Cooled Radial Turbine Rotor," Department of Aerospace Engineering & Applied Mechanics, University of Cincinnati, NASA CR-137951, Advanced Systems Research Office, Mar. 1977.

Harper, W. B., Jr., Kidwell, J. R., Large, G. D., Matuschak, P. E., Humble, C. E., Henry, C. L., and MacDougall, D. A., "1-2 pps Small Turbine Advanced Gas Generator (STAGG) Program (U)," AIResearch Manufacturing Company of Arizona, USAAMRDL TR-76-12, Applied Technology Laboratory, Mar. 1977. (CONFIDENTIAL)

Head, Robert E., "Erosion Protection for the AH-1G Low Radar Cross-Section Main Rotor Blade Volume I-Sand and Rain Erosion Evaluation," Hughes Helicopters, USAAMRDL TR-76-40A, Applied Technology Laboratory, Jan. 1977.

Head, Robert E., "Erosion Protection for the AH-1G Low Radar Cross Section Main Rotor Blade, Volume II – Radar Cross Section Evaluation (U)," Hughes Helicopters, USAAMRDL TR-76-40B, Applied Technology Laboratory, Jan. 1977. (SECRET)

Hosny, W., and Tabakoff, W., "Numerical Solution for the Temperature Distribution in a Cooled Guide Vane Blade of a Radial Gas Turbine," *Dept. of Aerospace Engineering, University* of Cincinnati, NASA CR-137943, Advanced Systems Research Office.

Hsieh, P. Y., "Rotorcraft Flight Simulation With Coupled Rotor Aeroelastic Stability Analysis Vol. III – Programmer's Manual," Bell Helicopter Textron, USAAMRDL TR-76-41C, Applied Technology Laboratory, May 1977.

Irons, G. Steele, "Refinement of Casting Techniques for Small Air-Cooled Turbine Blades – Phase 1," General Electric Co., USAAMRDL TR-76-37, Applied Technology Laboratory, Feb. 1977.

Jagacinski, R. J., Miller, D. P., Gilson, R. D., and Ault, R. T., "Evaluation of Kinesthetic-Tactual Displays Using a Critical Tracking Task," Ohio State University, Proceedings of the 13th Annual Conference on Manual Control, Advanced Systems Research Office, Jun. 1977.

Khalil, I., Tabakoff, W., and Hamed, A., "An Investigation of Viscous Losses in Radial Inflow Nozzles," Dept. of Aerospace Engineering & Applied Mechanics, University of Cincinnati, NASA CR-137942, Advanced Systems Research Office.

King, Paul A., and Givens, Robert L., "Investigation of Factors Controlling Engine Scheduled Overhaul-T53/T55," Avco Lycoming Engine Group, USAAMRDL TR-77-9, Applied Technology Laboratory, May 1977.

Magenheim, Bertram, and Hains, Frank, "Feasibility Analysis for a Microwave Deicer for Helicopter Rotor Blades," Mechanics Research, Inc., Applied Technology Laboratory, May 1977.

Marsh, James E., "Input Data, ARMS Model Simulation of the OH-58A in an Army Tactical Environment," COBRO Corp., USAAMRDL TR-77-15, Applied Technology Laboratory, May 1977.

Mathur, P. S., and Bartos, J. L., "Development of Hot Isostatically Pressed Rene 95 Turbine Parts," General Electric Co., USAAMRDL TR-76-30, Applied Technology Laboratory, May 1977.

Mayo, William T., Jr., "Study of Photon Correlation Techniques for Processing of Laser Velocimeter Signals," Science Applications, Inc., NASA CR-2780, Structures Laboratory, Feb. 1977.

Mazelsky, Bernard, "Investigation of an Aluminum Rolling Helix Crash Energy Absorber," ARA, Inc., USAAMRDL TR-77-8, Applied Technology Laboratory, May 1977.

McGrogan, F., "Oil-Air Mist Lubrication for Helicopter Gearing," Sikorsky Aircraft Div., NASA CR-135081, Propulsion Laboratory, Dec. 1976.

McLarty, Tyce T., "Rotorcraft Flight Simulation With Coupled Rotor Aeroelastic Stability Analysis Vol. 1-Engineer's Manual," Bell Helicopter Textron, USAAMRDL TR-76-41A, Applied Technology Laboratory, May 1977.

Mejdrich, R. R., "Advanced Technology Servicing Equipment for Army Aircraft," Air Research Div., USAAMRDL TR-77-33, Applied Technology Laboratory, Oct. 1977.

O'Brien, Michael, "Development of a Short-Length Self-Acting Seal (Final Report)," Avco Lycoming Div., NASA CR-135159, Propulsion Laboratory, Nov. 1976.

Ormsbee, Allen I., "Low Speed Airfoil Study," NASA CR-153914, Structures Laboratory, Jul. 1977.

Parker, W. H., "DSTR/501-M62B Dynamic Interface Critical Speed Problem," Detroit Diesel Allison, USAAMRDL TR-77-12, Applied Technology Laboratory, May 1977.

Paterson, Robert W., and Amiet, Roy K., "Acoustic Radiation and Surface Pressure Characteristics of an Airfoil Due to Incident Turbulence," United Technologies Research Center, NASA CR-2733, Structures Laboratory, Sept. 1976.

Posingies, Walter, "Production Suitability of an Electorform Conductive-Wax Process for the Manufacture of Fluidic Systems," Honeywell, Inc., USAAMRDL TR-77-2, Applied Technology Laboratory, Apr. 1977.

Rackiewicz, Joseph J., "Bearingless Helicopter Main Rotor Development Volume II-Combined Load Fatigue Evaluation of Weathered Graphite/Epoxy Composite," Sikorsky Aircraft Div., NASA CR-145144, Structures Laboratory, Dec. 1976.

Schockey, Gerald A., Williamson, Joe W., and Cox, Charles R., "AH-1G Helicopter Aerodynamic and Structural Loads Survey," Bell Helicopter Textron, USAAMRDL TR-76-39, Applied Technology Laboratory, Feb. 1977.

Shiembob, L. T., "Development of a Plasma Sprayed Ceramic Gas Path Seal for High Pressure Turbine Applications (Final Report)," Pratt & Whitney Aircraft Group, NASA CR-135183, Propulsion Laboratory, Apr. 1977.

Silva, J. P., and Hammond, J. L., "Reliability, Maintainability, and Performance Issues in Hydraulic System Design," Boeing Vertol Company, USAAMRDL TR-77-6, Applied Technology Laboratory, Jun. 1977.

Troth, D. L., "Low-Emissions Combustor Demonstration," Detroit Diesel Allison Div. General Motors Corp., USAAMRDL TR-76-29, Applied Technology Laboratory, Mar. 1977.

Van Gaasbeek, James R., "Rotorcraft Flight Simulation With Coupled Rotor Aeroelastic Stability Analysis Vol. 11-User's Manual," Bell Helicopter Textron, Applied Technology Laboratory, May 1977.

APPENDIX C

RTL PERSONNEL SERVING ON TECHNICAL AND SCIENTIFIC COMMITTEES

COMMITTEE	AFFILIATION	INDIVIDUAL
AMERICAN HELICOPTER SOCIETY		
Aerodynamics Committee	Member	Dr. Fredric H. Schmitz
	Member	Mr. W. D. Vann
	Member	Mr. Gene J. Bingham
AHS Technical Council	Member	Mr. Frederick H. Immen
	Member	Mr. John W. White
Aircraft Design Committee	Member	Dr. M. P. Scully
Avionics, Systems & Human Factors Technical Committee	Vice-Chairman	Dr. Richard S. Dunn
Dynamics Committee	Chairman	Dr. Robert A. Ormiston
	Member	Mr. Edward A. Austin
Handling Qualities Committee	Member	Mr. David L. Key
	Member	Mr. Robert P. Smith
Manufacturing & Product Assurance Committee	Member	Mr. L. Thomas Mazza
Operations & Testing Technical Committee	Member	Mr. John C. Wilson
Propulsion Technical Committee	Member	Mr. LeRoy T. Burrows
Structures & Materials Committee	Member	Dr. Raymond E. Foye
	Member	Mr. G. T. Singley, III
Structural Dynamics Technical Committee	Member	Dr. Dewey H. Hodges
AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS		
Air Breathing Propulsion Technical Committee	Member	Mr. Nicholas C. Kailos
Atmospheric Flight Mechanics Technical Committee	Member	Mr. David L. Key
V/STOL Aircraft Systems Technical Committee	Member	Mr. John P. Rabbott
AMERICAN MATHEMATICAL SOCIETY		
Mathematical Reviews	Reviewer	Dr. James T. Wong
	Reviewer	Dr. Harold Law
AMERICAN SOCIETY OF MECHANICAL ENGINEERS		
Aircraft Gas Turbine Committee	Member	Mr. Henry L. Morrow
Gas Turbine Division Turbomachinery Committee	Chairman	Mr. Robert A. Langworthy
Power Transmission & Gear Committee	Member	Mr. Wayne A. Hudgins
	Member	Mr. James Gomez, Jr.
DEFENSE ATOMIC SUPPORT AGENCY		
Committee on Military Application of Blast Simulators	Member	Mr. Stephen Pociluyko

COMMITTEE	AFFILIATION	INDIVIDUAL
DEPARTMENT OF DEFENSE		
Federal Working Group on Optical Transparent Materials	Member	Mr. Joseph H. McGarvey
	Member	Mr. Thomas E. Condon
Government Agency Aircraft Seating Systems Working Group	Member	Mr. George T. Singley, III
Government Committee on Engine Component Life Prediction (DOD/NASA)	Member	Mr. Jan M. Lane
Government Committee on Engine Seals (DOD/NASA)	Member	Mr. Jan M. Lane
Interagency Advanced Power Group, Mechanical Working Group	Member	Mr. Henry L. Morrow
Interagency Coordination Group for Application of Ceramics to Turbine Engines (DOD/NASA/ERDA)	Member	Mr. Graydon A. Elliot
Intergovernment Agency Ad Hoc Group for V/STOL Downward Measurement & Reduction	Member	Mr. Richard I. Adams
JCS Joint Technical Coordinating Group for Aircraft Survivability		
Design Criteria & Industry Interface Subgroup	Chairman	Mr. Vincent L.J. Di Rito
Technology R&D Subgroup	Member	Mr. James T. Robinson
Airframe & Materials Ad Hoc Committee	Member	Mr. Frederick H. Immen
Countermeasures Subgroup	Vice-Chairman	Mr. Joe D. Ladd
Design Criteria Subgroup	Member	Mr. Stephen Pociluyko
Flight Controls & Hydraulics Subgroup	Member	Mr. Stephen Pociluyko
Fuel Systems Subgroup	Member	Mr. Charles Pedriani
Laser Countermeasures Subgroup	Member	Mr. Earl Gilbert
Methodology Standardization & Analysis Panel	Member	Mr. D. J. Merkley
Personnel & Aircrew Protection Committee	Member	Mr. James T. Robinson
Propulsion Systems Subgroup	Member	Mr. Harold Holland
Simulation Technology Coordination Group (DOD/NASA)	Member	Dr. David L. Key
Survivability Assessment Subgroup	Member	Mr. E. V. Merritt
Joint Technical Coordinating Group on Fluidics		
Aircraft & Fabrication Subgroup	Member	Mr. George W. Fosdick
Subpanel on National Aeronautics Facilities	Member	Mr. H. Andrew Morse
Tri-Service Coordinating Committee on 6.1 Research	Member	Mr. John Acurio
Tri-Service & Leads to NATO Aircrew Station Standardization Panel	Member	Dr. Richard S. Dunn
Tri-Service/NASA Aircrew Workload Measurement Coordinating Committee	Member	Dr. Richard S. Dunn

COMMITTEE	AFFILIATION	INDIVIDUAL
DEPARTMENT OF DEFENSE (CONTINUED)		
Tri-Service Propulsion Committee on Small Engine Technology	Member	Mr. John Acurio
Tri-Service Structures Technology Coordinating Paper	Member	Mr. L. Thomas Mazza
TTCP Action Group HAG-2 (Engine Health Monitoring)	Member	Mr. S. Blair Foteate, Jr.
TTCP Action Group HAG-3 (Helicopter Icing)	Member	Mr. Richard I. Adams
TTCP Action Group HAG-4 (Aerodynamics & Dynamics)	National Leader	Mr. Andrew W. Kerr
Subgroup H	Member Member Member	Mr. Herman I. MacDonald Mr. Donald J. Merkley Mr. Arthur E. Ragosta
TTCP Technical Panel H-3 (Aeronautical Vehicle Fatigue)	Member	Mr. Robert S. Berrisford
TTCP Technical Panel HTP-4 (Helicopter Operations Technology)	National Leader	Mr. Thomas L. Coleman
DEPARTMENT OF THE AIR FORCE		
Combat Damage Information Center	Member	Mr. Vincent L.J. Di Rito
DEPARTMENT OF THE ARMY		
AAH System Safety Group	Member Member Member Alternate	Mr. Richard E. Bywaters Mr. George T. Singley, III Mr. Vincent L.J. Di Rito LTC Dwain T. Moentmann
Air Vehicle Ad Hoc Working Group for Exchange of RPV Data (w/United Kingdom)	Member Member	Mr. Gary N. Smith Mr. Russell O. Stanton
Army Research Office		
Univ. of Calif. Berkeley Contracts for Planning & Control Under Risk & for Adaptive Approximation Techniques in Optimization	Scientific Liaison	Dr. Harold Law
Camouflage/Countersurveillance Program	Representative	Mr. Earl C. Gilbert
Cooperative Research Project in Aircraft Vulnerability Reduction (w/United Kingdom)	Member	Mr. I. E. Figge
Cooperative Research Project in Helicopter Dynamics (w/France)	Project Officer	Dr. Irving C. Statler
Flight Safety Board	Member	Mr. Vincent L.J. Di Rito
Information Exchange Program in Fuel Systems Vulnerability (w/United Kingdom)	Member	Mr. Charles M. Pedriani
Joint Combat Development Command/Army Material Development & Readiness Command Working Group for Aviation Ground Support, New GSE Acquisition Panel	Member	Mr. Solomon G. Riggs
Mobile Sources Environmental Control Program	Member	Mr. Kent F. Smith
Patent Evaluation Committee	Member	Mr. I. E. Figge
Subscriber Committee for DARCOM Midwest Regional Scientific & Engineering Computer Center	Member	Mr. William M. Sessoms

COMMITTEE	AFFILIATION	INDIVIDUAL
DEPARTMENT OF THE ARMY (CONTINUED)		
Tri-Service Manufacturing Technology Advisory Group		
Metals Technical Subcommittee	Member	Mr. Albert E. Easterling
Nonmetals Technical Subcommittee	Member	Mr. L. Thomas Mazza
	Alternate	Mr. Philip J. Haselbauer
U.S. Army Aviation Research and Development Command		
AVRADCOM Committee for Nondestructive Testing	Member	Mr. William L. Andre
	Alternate	Mr. Philip J. Haselbauer
Production Engineering Measures (PEM) Review Board	Member	Mr. L. Thomas Mazza
	Alternate	Mr. Philip J. Haselbauer
Aircraft Operation and Test Procedures Board	Member	LTC T. K. Wright
U.S. Army Materiel Development and Readiness Command		
AAMRC Army Symposium on Solid Mechanics Committee	Member	Dr. Raymond E. Foye
Government Fluidic Coordinating Working Group	Member	Mr. George W. Fosdick
Mechanics of Materials Technical Working Group	Member	Mr. Arthur J. Gustafson
Production Engineering Measures Review Board	Member	Mr. Frederick H. Immen
	Member	Mr. Everett E. Bailey
Scientific & Engineering Computing Council	Member	Mr. H. Mike Kodani
	Alternate	Mr. William M. Sessoms
Terminal Homing Data Bank Committee	Member	Mr. Joe D. Ladd
Vulnerability Analysis Team	Chief	Mr. E. V. Merritt
	Member	Mr. Charles M. Pedriani
	Member	Mr. Richard E. Bywaters
	Member	Mr. W. L. Peterson
	Member	Mr. Earl C. Gilbert
	Member	Maj. E. Hathaway
U.S. Army Mathematics Steering Committee	Member	Dr. Harold Law
	Member	Dr. James T. Wong
Operations Research Subcommittee	Member	Dr. Harold Law
Probability Subcommittee	Member	Dr. James T. Wong
INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS		
Aerospace & Electronic Systems Committee	Member	Mr. Richard E. McFarland
Automatic Controls Committee	Member	Mr. Richard E. McFarland
NATIONAL ACADEMY OF SCIENCES		
Transportation Research Board Aviation Subcommittee	Member	Mr. Francis P. McCourt

COMMITTEE	AFFILIATION	INDIVIDUAL
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION		
Ad Hoc Committee for the Review of Structural Dynamics Technology for Wind Power Turbines	Member	Dr. Robert A. Ormiston
Ad Hoc Committee for Structural Dynamics Long Range Planning	Member	Dr. Robert A. Ormiston
Aviation Safety Reporting System Review Group	Member	LTC T. K. Wright
Composites Interdependence Panel Executive Committee	Member	Mr. Frederick H. Immen
Helicopter Theme Team	Member	Mr. H. Andrew Morse
R&D Simulator Advisory Committee	Member	LTC T. K. Wright
Research & Technology Advisory Council (RTAC)	Member	Mr. Frederick H. Immen
Committee on Aeronautical Propulsion	Member	Mr. John W. White
Informal Committee on Rotorcraft Technology	Member	Mr. John W. White
RSRA Project Review Panel	Cochairman	Mr. John L. Shipley
NATIONAL RESEARCH COUNCIL		
National Materials Advisory Board Committee on Control of Fretting-Initiated Fatigue	Member	Dr. Robert C. Bill
NORTH ATLANTIC TREATY ORGANIZATION		
Advisory Group for Aerospace R&D		
Flight Mechanics Panel	U.S. National Coordinator Member	Dr. Irving C. Statler
Fluid Dynamics Panel	Member	Dr. William J. McCroskey
Propulsion & Energetics Panel (PEP)	Member Member	Mr. Charles M. Pedriani Mr. John Acurio
WG/06 Subgroup A	Member	Mr. Henry L. Morrow
Structures & Materials Panel	Member	Mr. Robert S. Berrisford
Mutual Assistance Camouflage & Concealment Working Party	Member	Mr. Earl Gilbert
SOCIETY OF AERONAUTICAL WEIGHT ENGINEERS		
Government-Industry Committee	Member	Mr. William H. Marr
SOCIETY OF AUTOMOTIVE ENGINEERS		
Aerospace Control & Guidance Systems Committee	Member	Mr. Richard L. Scharpf
Aerospace Secondary Power Systems Committee	Member	Mr. Roger Furgurson
Aircraft Engine Monitoring (E-32) Committee	Member	Mr. S. Blair Poteate, Jr.
Aircraft Environmental Control Systems Committee	Member	Mr. Richard I. Adams
Engine Transient Performance Committee	Member	Mr. Paul Chesser

COMMITTEE	AFFILIATION	INDIVIDUAL
SOCIETY OF AUTOMOTIVE ENGINEERS (CONTINUED)		
Gas Turbine Engine Committee	Member	Mr. Henry L. Morrow
Helicopter Powerplants Committee	Member	Mr. LeRoy Burrows
SAE-5B Fuel Pump Panel	Member	Mr. Roger Furgurson
SUBSONIC AERODYNAMIC TESTING ASSOCIATION	Representative	Mr. Patrick A. Cancro
	Representative	Mr. John E. Yeates
	Representative	Mr. Frank A. Lazzeroni
STANFORD/NASA INSTITUTE FOR AERONAUTICS AND ACOUSTICS	Member	Dr. Irving C. Statler
	Member	Dr. Fredric H. Schmitz
	Member	Dr. Robert A. Ormiston
	Member	Mr. William J. McCroskey
	Member	Mr. David L. Key
	Member	Mr. H. Andrew Morse
U. S. CIVIL SERVICE COMMISSION		
Third Region Civil Service Rating Panel for Engineers/Scientists	Member	Mr. Arthur J. Gustafson
	Member	Mr. James T. Robinson
	Member	Mr. Herman P. Simon
	Member	Mr. Marion K. Taylor
	Member	Mr. James P. Waller
	Member	Mr. John W. White
	Member	Mr. John E. Yeates
San Francisco Region Civil Service Rating Panel for Senior Level Announcement	Member	Mr. Frederick H. Immen

APPENDIX D
LIST OF ABBREVIATIONS

AAH	Advanced Attack Helicopter
AAWS	Advanced Aerial Weapons System
ABC	Advancing Blade Concept
ADI	Alternating Direction Implicit
AEFA	Aviation Engineering Flight Activity
AGARD	Advisory Group for Aerospace Research and Development
AIF	Army Industrial Fund
AIRS	Accident Information Retrieval System
AMC	(Now DARCOM)
AMCAWS	Advanced Medium Caliber Aircraft Weapon System
AMRDL	(Now RTL)
ANP	Annual Narrative Program
APBI	Advanced Planning Briefing for Industry
API	Armor-Piercing Incendiary
APU	Auxiliary Power Unit
ARMS	Aircraft Reliability and Maintainability Simulation
ARPA	Advanced Research Project Agency
ARRADCOM	(U.S. Army) Armament R&D Command
ASA	Army Security Agency
ASE	Aircraft Survivability Equipment
ASH	Advanced Scout Helicopter
ASRO	Advanced Systems Research Office
ASTD	Advanced Structures Technology Demonstrator
ATDE	Advanced Technology Demonstrator Engine
AUTOCUE	Automatic Target Cueing System
AVLABS	(U.S. Army) Aviation Materiel Laboratories
AVRADCOM	(U.S. Army) Aviation R&D Command
AVSCOM	(Now AVRADCOM)
BDT	Ballistic Damage Tolerant
BHT	Bell Helicopter Textron
BIU	Battery Interface Unit
BMR	Bearingless Main Rotor
CADDE	Control Automatic Digital Data Encoder
CLAH	Container Lift Adapter Helicopter
COEA	Cost and Operational Effectiveness Analysis
CONUS	Continental United States
COPE	Name of the Remote Job Entry Terminal
CTR	Controllable Twist Rotor
DA	Department of the Army
DARCOM	(U.S. Army) Material Development and Readiness Command
dB	Decibel
dc	Direct Current
DCSOPS	Deputy Chief of Staff for Operations and Plans
DCSRDA	
DOD	Department of Defense
E&S	Engineer and Scientist
E/D	Edge Distance
EEO	Equal Employment Opportunity
EMI	Electromagnetic Interference
FAA	Federal Aviation Administration
FAARP	Forward Area Rearm/Refuel Point
FCS	Flight Control System
FDAS	Fatigue Damage Recording System
FDTE	Force Development Testing and Evaluation
FLAIR	Flex Beam Air Resonance
FLIR	Forward Looking Infrared
FORSCOM	(U.S. Army) Forces Command
FPS or fps	Feet Per Second
FSAA	Flight Simulator for Advanced Aircraft
ft	Feet
FY	Fiscal Year
g	Gravity
gm	Gram
GS	General Schedule (Grade Level)
HE	High Explosive
HEI	High Explosive Incendiary
HEI-T	High Explosive Incendiary-Tracer
HEL	(U.S. Army) Human Engineering Laboratory
HELLFIRE	Helicopter Launched Fire and Forget Autitank Missile System
HERS	High Energy Rotor System
HIGAD	High Impulse Gun Airborne Demonstration
HLH	Heavy Lift Helicopter
HP or hp	Horsepower
HQ	Headquarters
HZ	Hertz
IBM	International Business Machines
IFR	Instrument Flight Rules
IGE	In-Ground Effect
IOC	Initial Operational Capability
IPAD	Integrated Program for Aerospace-Vehicle Design
IR	Infrared
IR&D	Independent Research and Development
ITAV	Individual Tactical Aircraft System
KTAS	Knots True Air Speed
LAH	Light Attack Helicopter
lb	Pound
LLNO	Low Level Night Operation
LOA	Letter of Agreement
LOGMOD	Logic Model
LUH	Light Utility Helicopter
LV	Laser Velocimeter
mm	Millimeter
MBO	Management By Objectives
MCTR	Multicycle CTR
MERADCOM	(U.S. Army) Mobility Equipment Research and Development Command
MIRADCOM	(U.S. Army) Missile R&D Command
MM&T	Manufacturing Methods and Technology
MOU	Memorandum of Understanding
MQT	Material Qualification Test
MRB	Main Rotor Blade
MTBF	Mean Time Between Failure
NASA	National Aeronautics and Space Administration
NASTRAN	NASA Structures Analysis
NATO	North Atlantic Treaty Organization
NDI	Nondestructive Inspection
NDT	Nondestructive Testing
NiCad	Nickel-Cadmium
NOE	Nap-of-the-Earth
ODCSOPS	Office of the Deputy Chief of Staff for Operations and Plans

OMA	Operation and Maintenance, Army
OPR	Objectives, Priority and Rationale
PRB	Program Rotor Body
PEMA	Procurement of Equipment and Missiles, Army
PIO	Pilot Induced Oscillation
PM	Project/Product Manager
PM-TRADE	Project Manager, Training Devices
PSDE	Preliminary Systems Design Engineering
psi	Pounds per Square Inch
R&D	Research and Development
R&M	Reliability and Maintainability
RAM	Reliability, Availability and Maintainability
RCS	Radar Cross Section
RDM	Rotor Dynamics Model
RDT&E	Research, Development, Test, and Engineering
RFP	Request for Proposal
RFQ	Request for Quote
RIO	Return on Investment
ROC	Required Operational Capability
RPM or rmp	Revolutions Per Minute
RPV	Remotely Piloted Vehicle
RSRA	Rotor System Research Aircraft
RSTA/D	Reconnaissance, Surveillance, Target Acquisition and Designation
RTA	Rotor Test Apparatus
RTL	(U.S. Army) Research and Technology Laboratories (AVRADCOM)
S&T	Science and Technology
sec	Second
SFC	Specific Fuel Consumption
SHP	Shaft Horsepower
SIRS	Structural Integrity Recording System
SLAMMO	Separate Loaded Ammunition
SOTAS	Stand-Off Target Acquisition System
SPEF	Single Program Element Funding
SPF	Single Project Funding
SRIO	Systems Research Integration Office
SSEB	Source Selection Evaluation Board
STAGG	Small Turbine Advanced Gas Generator
STOG-77	Science and Technology Objectives Guide – 1977 (Confidential)
SURVIV	Survivability Model
SUR/VTOL	Surveillance/Vertical Takeoff and Landing Aircraft System
TDI	Training and Doctrine Institute
TILO	Technical Institute Liaison Office
TIMS	The Institute of Management Sciences
TMI	Terrain Management Institute
TRADOC	(U.S. Army) Training and Doctrine Command
TRADS	Transportation Research and Development Support
TRADSCOM	Transportation Research and Development Command
TRASANA	TRADOC Systems Analysis Activity
TRECOM	Transportation Research and Engineering Command
USAF	United States Air Force
UTTAS	Utility Tactical Transport Aircraft System (Black Hawk)
VR	Vulnerability Reduction
V/STOL	Vertical/Short Takeoff and Landing
V/STOLAND	V/STOL Advanced Autopilot System
VTOL	Vertical Takeoff and Landing
W/D	Width/Hole Diameter Ratio